S. Hrg. 101-1039

SHORTAGE OF ENGINEERS AND SCIENTISTS

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED FIRST CONGRESS

SECOND SESSION

ON

TRAINING SCIENTISTS AND ENGINEERS FOR THE YEAR 2000—THE NATIONAL SCIENCE FOUNDATION'S ROLE

MAY 8, 1990

Printed for the use of the
Committee on Commerce, Science, and Transportation

U.S. GOVERNMENT PRINTING OFFICE
35-732 O WASHINGTON : 1990

For sale by the Superintendent of Documents, Congressional Sales Office
U.S. Government Printing Office, Washington, DC 20402

S261-23

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SHORTAGE OF ENGINEERS AND SCIENTISTS

TUESDAY, MAY 8, 1990

U.S. Senate,
Committee on Commerce, Science, and Transportation,
Subcommittee on Science, Technology and Space,
Washington, DC.

The subcommittee met, pursuant to notice, at 10:04 a.m., in room SR-253, Russell Senate Office Building, Hon. Albert Gore, Jr., [chairman of the subcommittee] presiding.

Staff members assigned to this hearing: Mike Nelson, professional staff member and Fiona Branton, minority staff counsel.

OPENING STATEMENT BY SENATOR GORE

Senator Gore. Good morning. Today, the Science Subcommittee will examine an issue that should concern anyone who cares about the state of American science and technology, namely the training of the next generation of scientists and engineers. Over the past few years, report after report has predicted that our country will not have enough qualified scientists and engineers to meet the scientific and technological challenges of the next century. This issue has come up at almost every Subcommittee hearing that I have chaired during the last two years, whether the hearing was on NASA, global change research, computer research—whatever the field—someone has inevitably raised the question, are we going to have the talent needed to do the job.

At a hearing last year, Dr. James Fletcher, then Administrator of NASA, testified that 70 percent of the senior executives at NASA and 45 percent of the entire staff at NASA was eligible for retirement. Over the next 10 years or so, these people will have to be replaced if NASA is to fulfill its mission. The situation is similar at the Department of Energy, at the national labs, at other Federal agencies, and yet we are seeing fewer and fewer students interested in pursuing careers in science and engineering.

Our universities are facing a wave of retirements in the next few years as the tens of thousands of professors hired after Sputnik start to retire. These retirements will come just as the children of the baby boomers start to enter college, increasing college enrollments and creating a need for new faculty. It typically takes 10 to 12 years for a college freshman to earn a Ph.D, so the Ph.Ds who will replace those retiring professors are in college right now.

We have to find ways to nurture students and encourage them to pursue advanced degrees in science and engineering. If we do not, American colleges and universities will lack the qualified faculty they need to teach future generations of students, to do research and to teach the elementary and secondary science and math teachers this Nation needs. The entire science education infrastructure could be endangered as a result.

Perhaps the most serious consequences of the projected shortfall of scientists and engineers would be felt by American industry. Computer companies, aircraft manufacturers and other high tech companies hire thousands of scientists and engineers each year, and so do construction companies, steel companies, investment firms and State and local governments. There are very few companies that can afford to ignore science and technology. That would be like committing corporate suicide these days. If a company does not keep up with technology, it cannot hope to keep up with the competition.

Yet still, students are showing less, not more, interest in science and engineering. According to Dr. Alan Bromley, the President's science advisor, surveys of college freshman show that in the last four years there has been a one-third drop in the number of freshmen intending to pursue careers in science and engineering, a one-quarter drop in the number of freshmen intending to major in mathematics and physics, and an alarming two-thirds drop in the number of freshmen planning to major in computer science. There have been dozens of reports documenting the need to increase the number of people going into science and engineering.

So at today's hearing we will examine what we need to do about this. Hundreds of policy recommendations have been made, and most of them cost money. Clearly, in this era of tight budgets we cannot implement all of these recommendations. Thus, the Congress will have to make some difficult choices about the way we support science and engineering in this country. As we set priorities within the NSF budget, we have to determine how much money is needed for NSF science and engineering education programs and how much is needed for NSF research programs. What are the trade-offs here?

In recent years, Congress has provided major increases for NSF's education programs, especially for elementary and secondary science education. The research programs have not done as well. Research budgets are tight, and excellent grant proposals unfortunately are being turned down. University researchers are as a result growing increasingly frustrated. Small science seems to be under particularly harsh pressure. This is having an impact on the training of new scientists and engineers. Undergraduates and especially graduate students see the tight research budgets, the rejected proposals, their professors' frustration, and more and more often they are opting to change their career plans.

At today's hearing, we will try to determine the proper balance between education programs and research programs at NSF. We will also examine where the Federal Government should focus its efforts to increase the number of scientists at the elementary and secondary level, at the undergraduate level, at the graduate level. Finally, we have to determine the proper distribution of NSF research and education program funding.

Most of the university research done in this country is done at about 100 large top-flight universities and institutions. Consequently, these schools receive the majority of NSF funding and train most of our Ph.Ds in science and engineering. However, other smaller undergraduate schools play a key role as well. Half the Ph.Ds awarded in the U.S. go to students who did their undergraduate work at smaller four-year colleges or universities devoted not to research primarily but to education. Should NSF and other Federal agencies be providing more funding to these schools?

The Congress and NSF have been struggling with these issues for many years, but the issues are becoming more pressing. We need action soon. More and more, America's competitiveness depends directly on the men and women who are developing and applying new technologies. Our health depends on researchers finding new ways to cure disease. The quality of our environment depends on scientists and engineers finding new ways to protect the planet's ecosphere. So many of the questions we face today require scientific and technological answers. We need to ensure that we have the men and women trained adequately to provide those answers.

Now, we have got a real good witness list today—one witness alone and then a panel of three—and our first lead-off witness is Eric Bloch, who has been Director of NSF for almost six years now. He is an electrical engineer by training, and before coming to NSF worked at IBM, where he helped to create the first commercially successful mainframe computer. He is a frequent witness before our Subcommittee, and a personal friend, and I am delighted to welcome you again, Mr. Bloch. Without objection, your entire prepared remarks will be inserted in the record in full and we invite you to proceed as you see fit.

I do want to say for the record that although many witnesses at hearings over the years have focused the attention of this Subcommittee on this subject, I want to acknowledge the key role that your advice and counsel has played in the thinking of our Subcommittee in deciding to make this one of our top priorities, because the time has indeed come to not simply talk about it, but take some constructive action to deal with this problem, and I appreciate the sustained attention you have given to it, and we look forward to hearing you today.

Senator Kasten do you wish to make a statement?

OPENING STATEMENT BY SENATOR KASTEN

Senator Kasten. Mr. Chairman, I am pleased that we will today be focusing on what could be a devastating shortage of scientific personnel at a time that this country will need them the most. With the globalization of the world's economies, America's students, universities and industry must have the training in the sciences that will support our economic growth.

Given the strong link between technological achivement and economic growth, which is needed to support our standard of living, let me state my strong commitment to avoiding a possible future scientific manpower shortage.

We could be facing a shortage of crisis proportions if government, the private sector and academia do not work together to produce the scientists and engineers of the future.

It's time for us to take up the President's challenge for American students to be first in the world in science and mathematics achievement by the year 2000. Unfortunately, as Director Bloch points out, current international comparisons of the science and math performance of our students routinely place us toward the bottom, of the list.

I am pleased that today we will be hearing from University of Wisconsin Chancellor Donna Shalala, in addition to our other distinguished witnesses. I would like to welcome her to the committee and commend her for her fine statement pointing out the problems challenging the nation in developing tomorrow's scientific leaders and integrating them into the scienctific community. I would also like to commend you Mr. Chairman, and staff, for inviting the distinguished administrator of one of America's premier teaching and research institutions. The problem facing us is multi-faceted, from teacher and university faculty training and retention, to student recruitment, to curriculum and facility improvements.

Much needs to be done. The Administration's plan to double the NSF budget by 1993 is a step in the right direction, and I support this move which would triple the educational portion of the NSF budget. The states and local school districts also have to be a part of the solution, in finding new and innovative ways to interest our young people in the sciences and translate that interest into career choices.

I am proud of Wisconsin's leadership role in being ninth in the country in awarding 536 new science and engineering doctorates in 1988, and in ranking 12th in academic research and developing performance. NSF has played a role in this, making 300 awards totalling almost $27 million in Wisconsin in support of research in Fiscal Year 1989. Last year the NSF also funded 52 fellowships in Wisconsin covering the tuition and a stipend for qualifying students.

Finally, all programs in this area have multiple benefits. As Chacellor Shalala outlines in her testimony, the Institute for Chemical Education—founded at the University of Wisconsin—is working to improve the teaching and curriculum of our secondary students.

Though 1600 teachers have been directly impacted by this excellent program, the benefit can be multiplied by each and every student with whom these teachers come into contact.

I look forward to hearing from our witnesses today and working with you, Mr. Chairman, so that the dire predictions of the manpower shortage do not come to pass.

Senator GORE. Thank you Senator Kasten.

Senator Pressler do you have a statement?

OPENING STATEMENT BY SENATOR PRESSLER

Senator PRESSLER. Mr. Chairman, thank you for calling this hearing today. I am very concerned, as you are, about the future of science and engineering manpower in this country.

Investment in science and engineering research and education is essential to the nation's economic future, national security, health care, and environmental well-being. We rely on scientists and engineers to discover new knowledge, invent new products, design more efficient processes, and develop solutions to an increasing number of complex social and environmental problems. However, in recent years the number of American students receiving graduate degrees in science and engineering has dropped precipitously. In engineering, more than half the graduate students are foreign born.

Where will the engineers and scientists we need for the future come from? Who will design our computers, telecommunications systems, space vehicles, and satellites? Who will develop new agricultural products to meet the challenges of an increasing world population and changing climate? Who will invent new vaccines to combat AIDS and other life-threatening diseases?

To meet the increasing demands of the 21st century, we need to increase the number of U.S. citizens who are studying science and engineering as undergraduates, and we need to encourage them to stay on to obtain graduate degrees. We can do this by providing better information about the market for scientists and engineers, so young people will be able to make rational career decisions. And we can increase the amount of financial support available for graduate work from the National Science Foundation through its graduate research fellowships and stipends.

We also need to broaden the base of science, without sacrificing the excellence of existing research. A broad base will involve more people in science, and realistically reflect the distribution of scientific achievement in the United States. The so-called second-tier schools educate over half the science and engineering baccalaureates. 40% of the students later receive graduate degrees. Expanding this base will benefit the university community and the country. Federal funds should not be concentrated in only a few institutions with the benefits accruing to only a few states. Instead, federal funds should be widely distributed to encourage competition and to ensure that all areas of the country realize the benefits of science education.

Other nations have recognized the importance of a skilled and trained scientific and engineering workforce to economic productivity and national well-being. They are expanding their investments in science and technology, including educating their young people, to meet the challenges of the next century. I hope that we in the United States will adopt a similarly long view when considering how to allocate our scarce budget resources.

Thank you, Mr. Chairman. I look forward to the testimony of today's witnesses.

Senator GORE. Thank you. Now we will hear from Mr. Bloch.

STATEMENT OF ERICH BLOCH, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Mr. BLOCH. Thank you very much, Mr. Chairman, and thank you for your kind words, and I appreciate the opportunity to testify before this committee.

I particularly want to commend this committee and your personal strong and consistent support for basic research and education and training. At a time when this nation faces many problems with respect to its economic competitiveness, the development of a technical work force and a scientifically literate public are vital to meeting the challenges of a global economy.

This committee and you, Mr. Chairman, are well aware of the problems we face in science, mathematics and engineering education in this country pervade all levels of the educational process. In fact, you mentioned a number of the indices that give us that much concern. Let me mention a few also.

Our primary and secondary schools do not provide adequate preparation in science and mathematics. Among college students, interest in the sciences and engineering has been declining and only 15 percent of entering freshmen plan to major in the natural sciences or engineering in 1988 compared with about 20 percent 20 years earlier.

Bachelor's degrees awarded in the natural sciences and engineering in 1988 have declined 3 percent from the previous year. In computer sciences alone the decline is almost 13 percent.

At the graduate level we are not producing the number of scientists and engineers that we will need to meet the challenges of a competitive world economy in the years ahead. We would be in a shortage position today in many critical disciplines for Ph.D.'s if it were not for foreign students pursuing doctoral degrees in this country and entering our marketplace.

As the college age population declines through the beginning of the next century, this situation will worsen. Equally important, women and minorities are becoming a larger part of the labor force and both have historically low participation rates in the sciences and in engineering.

At the recent education summit President Bush and the governors have challenged the nation with an ambitious goal. By the year 2000 U.S. students will be first in the world in science and mathematics achievement.

Achieving this goal will require a fundamental change in our strategy and indeed in our culture. As we proceed, there is understandable frustration at the pace with which education reform is realized. However, quick fixes by not addressing the need for long-term commitment and persistence are suspect. Our educational system is diffuse, and it is decentralized with the primary responsibility located at the state and local level. Nevertheless, it was made clear by President Bush and the governors that our success in improving the performance of our students depends on contributions from all institutions, private and public, state and local, Federal and on a commitment from every parent, every teacher, administration and student.

The National Science Foundation has a dual mission in research and in education, as you so aptly pointed out a few minutes ago, and NSF programs underscore the interdependence of these two activities and the mutually enriching nature of their relationship. The foundation's activities with respect to education are based on the premise that high quality education in science, engineering, mathematics and technology must be available at every education level. Only in this way can we prepare all students for a future in an increasingly technological world. NSF's programs in education are designed to be leveraged, to serve as models and examples and to encourage cooperation among all those who play a role in the educational process.

I have a number of figures and graphs that I distributed to you. Please refer to the first one labeled "Pre-college Activities." What you see here is essentially how we have progressed since 1982 in the funding of pre-college activities. I want to place it in context. Let me mention that in 1982 most NSF pre-college programs were phased out with funding down below the $4 million level. NSF's educational support was limited primarily to the graduate level in that year.

Since that time, as you can see on the next chart labeled "Education and Human Resources," the National Science Foundation has dramatically increased support for education at all levels from $34 million or 3 percent of our budget in 1982 to $357 million or 17 percent of the total in 1990. For 1991 NSF has requested an increase of 30 percent in this area to a level of $463 million or 20 percent of the total foundation budget.

As a result of NSF programs the number of students supported by NSF at all levels has about tripled since 1982 as you can see on figure number or graph number 3, where you see the progression since 1982 and also the category of support that we are giving to various groups and students as well as principal investigators. These increases are significant, not only in the NSF context, but within the broader Federal context as well. In the President's 1991 budget NSF represents about 45 percent of the total Federal investment in programs specifically targeted on science and engineering education and human resources. This is, in fact, the fastest growing part of our budget, as you can see from the last figure, "Major Theme Comparisons" where we are showing you essentially the last five years of progression in this area. While the administration has a commitment to doubling NSF's overall budget by 1993, the educational portion of our overall budget would be tripled by that year.

As mentioned before, we need to be concerned about the total educational process, and we are. At the pre-college level NSF supports projects for innovative pre-service and in-service teacher education. It also supports the development of new and high quality instructional materials and the application of advanced technologies to classroom activities. Our programs encourage alliances among scientists and engineers, colleges and universities, local teachers and schools through our private sector partnerships program. They also recognize the efforts of the very best elementary and secondary mathematics and science teachers in supporting improvement of teaching materials. We have involved the publishing industry in contributing resources and work with schools, school districts and academic curriculum development teams all across the nation. With the objective of stimulating student interest, our Young Scholars Program annually supports close to 5,000 high school students in real research experiences.

Our strategy with respect to undergraduate education is similar. Our total effort in this area is $90 million in 1990 and is scheduled to increase $48 million to $134 million in 1991. Our programs facilitate the acquisition of research instrumentation to improve laboratory instruction, make research experiences available to undergraduates, enhance faculty competence in undergraduate institutions and improve courses and curricula for all kinds of students, not just those intending to pursue technical careers.

These programs serve not only four-year and doctoral institutions but two-year and community colleges as well, both by means of their direct participation and by their use of materials developed in our curriculum or laboratory development activities.

At the graduate level the Foundation's activities are devoted specifically to training technical personnel for the nation's critical technical and research activities, be they in academia, government or industry. A trio of graduate fellowship programs, the regular program, women in engineering and minority fellowships provides support to nearly 3,000 of the nation's ablest graduate students every year preparing for careers in the sciences and engineering. NSF's research grants support an additional 12,000 graduate students working with principal investigators, and at the post-doctoral level several programs are designed to meet the needs of our universities for qualified faculty.

A critical element of all NSF programs is the strong concern for increasing the participation of underrepresented groups—women, minorities and the disabled—in the sciences and engineering. Without substantial improvement in this area the nation will be seriously handicapped in its efforts to meet the challenges of the highly competitive global economy.

Our career access program in the science and engineering education directorate supports efforts to increase the entry of women, minorities and the disabled into science, mathematics and engineering courses and programs and to encourage them into scientific careers. This program includes support for comprehensive regional centers which focus on increasing the pool of minorities prepared for further course work and careers in technical areas.

Two new programs included in our 1991 request will strengthen NSF's efforts with respect to underrepresented groups. First, faculty awards for women will recognize and support outstanding women in science and engineering. And the alliances for minority participation program by focusing on problems such as retention, support and inadequate student preparation will encourage undergraduate minority students to complete their B.S. degrees and to pursue graduate studies.

Cooperation among various parts of society is critical. This is a rationale for new statewide systemic initiative recently announced in conjunction with the National Governors Association. Its purpose is to catalyze the systemic comprehensive changes necessary for major improvements of the teaching and learning of science and mathematics at all educational levels. The program involves teachers, the business community, the state and local education entities, and the Federal research laboratories as appropriate and, in particular, the Eisenhower program of the Department of Education.

Cooperation is also a central feature of our 1991 proposal to initiate the alliances for minority participation program. This program will involve a wide range of participants in government, industry and the schools and universities in innovative alliances to improve participation of minorities in the nation's science and technology enterprise.

Cooperation is also an important objective within the government. In March Dr. Allan Bromley, Assistant to the President for Science and Technology, sent to Congress a congressionally mandated report on coordination between NSF and the Department of Education. The report spells out a series of specific areas of formal coordination that we have established with the Department.

While NSF and the Department of Education have well established roles with respect to science and engineering education, other agencies have significant contributions to make as well. NASA and the Department of Energy are responding to the need for a comprehensive national effort in this area by increasing the focus on education.

On a broader level, as Chairman of the Federal Coordinating Council on Science, Engineering and Technology, Dr. Bromley has created a committee on human resources and education. Congress has been highly supportive of improving science and engineering education in this country, and the consequences of this commitment are clearly visible in the strong increases in NSF support for education and human resources.

Congress can also contribute to this process by improving coordination among committees with oversight responsibilities for mathematics and science education and by paying closer attention to the strengths of the respective agencies as a basis of their own programs and of cooperative activities.

One of the most important contributions Congress can make is in the area of forbearance. As indicated earlier in this testimony, the Foundation's flexibility to innovate and to pursue excellence has been fundamental to the effectiveness of its programs and needs to be preserved.

In conclusion, Mr. Chairman, NSF has a compelling responsibility to provide national leadership for developing a comprehensive strategy for mathematics and science education in the USA. To this end, the Foundation is supporting innovative approaches to stimulate reform across the entire educational spectrum. As NSF continues to provide strong and sustained leadership and continued investments, we will work with other Federal agencies, the private sector, the state and local governments to improve the quality and effectiveness of a nationwide educational effort. Thank you, Mr. Chairman.

[The statement follows:]

ERICH BLOCH

DIRECTOR, NATIONAL SCIENCE FOUNDATION

TESTIMONY

U.S. SENATE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

MAY 8, 1990

Mr. Chairman, I appreciate the opportunity to testify before this Committee on the subject of science, mathematics, and engineering education. At a time when this Nation is facing many pressing problems with respect to its economic competitiveness, the development of a technical workforce and a scientifically literate public is vital to meeting the challenges of a knowledge-intensive global economy and technological change.

I particularly want to commend this Committee's strong and consistent support for basic research and for its interest in the broad range of issues, including education and training, that affect the productivity of our research system and the competence of our science and engineering workforce.

Education and Human Resources: A National Concern

Since this Committee is well acquainted with the status of science, mathematics, and engineering education in this country I need not dwell in detail on the problems we face. However, it is important to stress that these problems are not limited to one stage of the educational process; they pervade all levels.

- We have serious problems at the precollege level. Many of the Nation's high schools offer a poor selection of science and mathematics courses and, too frequently, the courses offered provide our students with poor preparation. International comparisons of the performance of students in the sciences and mathematics routinely place Americans toward the bottom of the list.

- Interest in the sciences and engineering among students has been declining. Only 15 percent of entering college freshmen planned to major in the natural sciences or engineering in 1988, compared to 20 percent in 1966.

- Our most recent data show that bachelor's degrees awarded in the natural sciences and engineering in 1988 have declined 3 percent from the previous year. In computer sciences alone, the decline is almost 13 percent.

- At the graduate level, we are not producing the number of scientists and engineers that we will need to meet the challenges of a competitive world economy in the years ahead.

- In critical disciplines, the number of doctorates would be much lower if it were not for foreign students. In engineering and mathematics, for example, foreign students constitute over 50% of doctoral recipients.

Demographic trends are likely to aggravate this situation through the beginning of the next century. For one thing, the college age population is declining. Equally important, women and minorities -- two groups with historically low participation rates in the sciences and engineering -- are becoming a larger part of the labor force.

Roles and Responsibilities

Our educational system is diffuse and decentralized, with the primary responsibility located at the state and local level. It is, therefore, at the state and local level that our national effort must be directed. Nevertheless, as was made clear at the recent education summit between President Bush and the governors and affirmed at the meeting of the National Governors' Association in February, our success in improving the performance of our students depends on contributions from all institutions, state, local, and Federal, public and private. It also depends on a commitment to excellence in achievement on the part of every parent, teacher, administration, and student.

With respect to science and mathematics education, President Bush and the governors have challenged the Nation with an ambitious goals:

> "By the year 2000, U.S. students will be first in the world in science and mathematics achievement."

Achieving this goal will require a fundamental transformation of our assumptions, our strategies, our habits, and, indeed, our culture to produce a durable transformation of the educational process, emphasizing excellence, continuity, and coherence. In today's competitive climate, we cannot afford an intermittent commitment, as was the case during the Sputnik era, to insure the availability of a competent technical work force.

Throughout the Nation, there is understandable frustration at the pace with which education reform is realized. However, quick fixes that fail to take into account the complexity and diffuseness of our educational system and the necessary involvement of the Federal, state, and local governments, parents, local school boards, businesses, and communities are suspect, not desirable, and not believable.

The National Science Foundation is strongly committed to exercising strong leadership with respect to improving the science and mathematics competence of our students and increasing the number and overall quality of our technical workforce. Furthermore, in this area, NSF performs a unique and strategic role. It is charged with improving and strengthening the national capacity for research in the sciences, mathematics, and engineering. NSF has a similar charge with respect to excellence in science, mathematics, and engineering education. Finally, it has a responsibility to monitor the health and quality of our achievement and performance in these areas.

This dual mission in research and education underscores the interdependence of research and education in this country, a unique arrangement that has resulted in the development of an enormously creative and productive research enterprise. Our research and education programs are pursued, therefore, in a complementary and synergistic manner. Specifically our education mission includes:

(a) precollege mathematics, science and technology education;
(b) undergraduate science, mathematics, and engineering education; and
(c) the other components of the science and engineering (S&E) process, including the maintenance of the S&E personnel essential to the nation's research capabilities through graduate fellowships and post graduate activities, and broadening participation by underrepresented groups and institutions.

The development of our technical talent pool and the enhancement of science literacy are NSF's highest priority, and Foundation programs are designed to address both the qualitative and quantitative deficiencies manifest at all critical points in the educational process.

NSF activities are based on the premise that high quality education in science, engineering, mathematics, and technology must be available at every educational level. Only in this way can we prepare all students for citizenship in an increasingly technological world and enable them to make intelligent choices about their advanced studies and careers.

NSF's role is to provide leadership and expertise and to serve as a catalyst in our national effort to introduce changes and improvements in our educational institutions. Our efforts in the educational area are designed to be leveraged, to serve as models and examples, and to encourage cooperation among all those who play a role in the educational process. The Foundation focuses its energies on initiatives of special importance and high merit, drawing on the advice and expertise of a broad community of scientists, educators, and administrators from all levels of the educational process.

History and Policy

To place NSF's current efforts in context, a historical perspective is in order.

In 1982, based on a perception that many of NSF precollege programs in mathematics and science education were unconnected and unevaluated, a decision was made to phase out most of them, limiting NSF educational support primarily to the graduate level. As shown in Appendix 1, the FY1982 budget for precollege education was down to $3.8 million. At the same time, it was clear that the Nation's need for an increasingly scientific and technical workforce called for a vigorous and well-reasoned plan to improve education in the sciences, mathematics, and engineering at all levels.

NSF, through its National Science Board's Education Commission, responded to this need with an action plan, "Precollege Education in Mathematics, Science and Technology," in September, 1983. This call for action, one of the first to address the needs at the precollege level, was soon followed by another National Science Board report in 1986, providing an explicit program plan for undergraduate science, mathematics and science education.

NSF' Long-Range Plan for the period of FY89-93 and the Strategic Plan for FY90-94 articulated the basis for Foundation programs in science and engineering education. The latter action plan, "Enhancing the Quality of Science, Mathematics, and Engineering Education in the United States," stipulated the following policy and objectives:

- Expanding excellence in science, mathematics, and engineering instructions at all levels, and supporting the acceptance of higher expectations of student and institutional performance;

- Developing attractive and effective new courses and curricula that provide consistent and coherent mathematics and science alternatives for consideration by those who administer education programs;
- Increasing the effectiveness of new teachers, faculty members, and supervisors;
- Developing the means for lowering the science and mathematics avoidance rates of female, minority, and disabled students, and stimulating their interest in scientific and technical careers; and
- Increasing the number of university faculty and researchers who give attention and effort to the improvement of science, mathematics, and engineering education, not just at the undergraduate level, but also, and particularly, at the precollege level.

NSF Activities in Human Resources and Education

As Appendix 2 shows, the National Science Foundation has dramatically increased support for education at all levels, from $34 million in FY1982 to $357 million in FY1990. During this period, education and human resources increased from 3% to 17% of the total budget. For FY1991, NSF has requested an increase of 30% in this area, to a level of $463 million, or 20% of the total Foundation budget. As a result of NSF programs, the number of students supported by NSF at all levels has about tripled since 1983. [See Appendix 3.]

These increases in support for science and engineering education are significant not only in the NSF context, but within the broader Federal context as well. In the President's FY1991 budget, NSF represents about 45 percent of the total Federal investment in programs specifically targeted on science and engineering education and human resources. Activities aimed at improving our human resource base in the sciences and engineering constitute 20 percent of the NSF budget. This is, in fact, the fastest growing part of our budget. Despite the fact that the Foundation received only slightly more than half our total requested increase, science and engineering education grew by 23 percent over FY1989. The Administration has a commitment to doubling NSF's overall budget by 1993. The educational portion of our overall budget, however, would be tripled by that year.

Strategy

The overall strategy that guides our efforts is that the educational process is a series of interdependent and interconnected stages, with links from pre-school through Grade 12, to undergraduate and to graduate study. The actions we take to influence the educational process at each level must recognize its unique importance and the inherent differences and needs that exist within each level while recognizing the relationship to and impact on other levels.

Our programs are designed to be catalytic and to leverage the finite resources available. They are also designed to address specific problems, opportunities, and needs central to the improvement of mathematics, science, technology and engineering education and training of students, teachers, and faculty at all levels. An important aspect of NSF's programs is special emphasis on underrepresented groups, institutions, and localities, such as urban school districts that require special focus and support.

NSF's overriding goal is to insure that the educational process stimulates the interest of students in the sciences and engineering, thereby assuring that the Nation has the scientists and engineers, the technically literate workforce, and educated public it needs for the decades ahead.

Programs: Support at all Levels:

NSF programs are significant not just for the level of the commitment they demonstrate, but also for the breadth of their support for all levels of the educational process, as shown by Appendix 4.

Precollege level:

At the precollege level, NSF supports innovative and model-building projects in teacher inservice education and in the preservice education of future teachers. It also supports the development of new, high quality instructional materials, the process of teaching and learning, and the application of advanced technologies to classroom activities. A full description of these programs is provided in Appendix 5. These programs, it should be noted, serve all students, not just those who will pursue majors and careers in mathematics, the sciences, or engineering.

We have refocused our training and retraining efforts to reach greater numbers of teachers. We have provided for the recognition of our very best elementary and secondary mathematics and science teachers to enhance the status of the profession. We have established teacher support networks to improve teacher interaction with practicing scientists and engineers. We have stressed the creation of alliances among scientists and engineers, colleges and universities, and local teachers and schools through our Private Sector Partnerships Program. Today, NSF programs are improving the subject matter competence of 12,000 elementary and secondary level mathematics and science teachers annually, an activity for which the budget has increased from $1.1 million in FY1983, to $25 million in FY1985, to $63.7 million in FY1989, and a request of $89 million for FY1991.

We have put in place new efforts to improve the materials and curriculum used to teach science and mathematics at the elementary and secondary level. We are supporting the use of innovative advanced technologies and materials within our elementary and secondary schools.

Through our Informal Science and Mathematics Education Program we have been successful in our efforts to involve the publishing industry by getting representatives to contribute resources and work with schools, school districts, and academic curriculum development teams all across the Nation. We have to do a better job of getting these new materials into the hands of our school systems. NSF's renewed coordination with the Department of Education insures increased dissemination of these materials through the Department's national Diffusion Network. The NSF FY1990 budget for this activity represents a doubling of the FY1986 funds.

We have also put in place programs that focus on stimulating and reinforcing the interest of high school students in science and mathematics. Our Young Scholars program annually supports close to 5000 students in real research experiences to stimulate their interest in science and mathematics and to help prepare them for the collegiate experience.

As shown in Appendix 5, these are some of the pieces of the total NSF elementary and secondary mathematics and science education effort. They represent only part of our strategy. Collectively, they emphasize stimulating and supporting a variety of incremental changes in educational systems. In our efforts to take a broad approach, we experiment and support a wide range of strategies that show promise for addressing important aspects of the problem. That is why we are investing in diverse projects from teacher training, to materials development, to scholarships and other science enrichment opportunities for students, to informal education activities, such as science museums, television programs, like Square One, 3-2-1 Contact, and other modes of informal mathematics and science education.

To insure the highest possible effectiveness of our programs, we are expanding our support for efforts to improve student, teacher, and program assessment techniques and instruments. We regularly encourage states and localities to avail themselves of materials and expertise developed through NSF-funded projects when they establish new standards for curricula and assessment.

Undergraduate education:

Our strategy with respect to undergraduate education is similar to that in the precollege area in its comprehensiveness. All NSF Directorates participate in this effort to take advantage of the mutually enriching relationship between education and research. Some programs are funded and managed entirely in the research directorates, and others in the Science and Engineering Education Directorate. All are coordinated by the Science and Engineering Education Directorate's Division of Undergraduate Science, Engineering, and Mathematics Education. Our total effort in this area in FY1990 is $90 million, and is scheduled to increase 48$ to $134 million in FY1991.

Our programs facilitate the acquisition of research instrumentation to improve laboratory instruction; make research experiences available to undergraduates; enhance faculty competence; and improve courses and curricula for all kinds of students, not just those intending to pursue technical careers.

These programs serve not only four year and doctoral institutions, but two year and community colleges as well, both by means of their direct participation and by their use of materials developed in our curriculum or laboratory development activities.

Graduate level:

At the graduate level, the Foundation's activities are devoted specifically to training technical personnel for the Nation's critical research activities, be they in academia, government, or industry.

O A trio of graduate fellowship programs -- the regular fellowship program, women in engineering, and minority fellowships -- provides direct support to nearly 3000 of the Nation's ablest graduate students preparing for careers in the sciences and engineering. These programs are aimed at U.S. nationals or permanent resident foreign students.

- NSF's research grants support an additional 12,000 graduate students working with principal investigators.
- At the postdoctoral level, several programs are designed to meet the need of our universities for qualified faculty.

Programs Focused on Underrepresented Groups:

A critical element of all NSF programs focused on human resources and science and engineering education is a strong concern for increasing the participation of underrepresented groups, that is, women, minorities, and the disabled in the sciences and engineering. Demographic trends clearly show that minorities and women will constitute a significantly increased portion of the workforce. Without substantial improvements in this area, this Nation will be seriously handicapped in its efforts to meet the challenges of the highly competitive global economy.

The Foundation has established cross-program efforts to correct the underrepresentation of women, minority, and disabled students in the sciences and mathematics. Two special NSF task forces, one on women and another on minorities, submitted reports whose recommendations serve as the basis for our current efforts. A third task force on the disabled will provide a similar basis for activities to encourage participation within this group as well.

Our Career Access Program in the Science and Engineering Education directorate supports efforts to increase the entry of women, minorities, and the disabled into science, mathematics, and engineering courses and programs and to encourage them into scientific careers. It includes support for Comprehensive Regional Centers to increase the pool of interested and eligible minorities who could become successful scientists and engineers. The Centers are comprehensive in their coverage of science, mathematics and engineering, in their spanning of educational levels, from elementary school through the baccalaureate; and in their emphasis on interaction among cooperating organizations and groups. Additional programs targeting minorities include Research Improvement in Minority Institutions, Minority Research Centers of Excellence, and Research Careers for Minority Scholars.

Women are encouraged to pursue careers in the sciences and engineer and to remain in them through the Research Opportunities for Women program, through Visiting Professorships for Women, and the Women in Engineering program.

Two new programs included in the FY1991 request will strengthen NSF efforts with respect to underrepresented groups further. Faculty Awards for Women will recognize and support outstanding women in science and engineering. The Alliances for Minority

Participation program, by focusing on problems such as retention, support, and inadequate student preparation will encourage undergraduate minority students to complete their baccalaureate degrees and to pursue graduate studies in science and engineering.

Partnerships and Leveraging:

Cooperation among various institutions will be critical to our success in bringing about a fundamental reform in science, mathematics, and engineering education and cooperative arrangements have been built into our programs. One example, mentioned earlier, is the Career Access Program.

We are also creating new programs that will build partnerships with States, localities, academia, and the private sector. With our FY1991 budget, NSF will actively pursue broad-based fundamental changes at the State and local levels as a complement to ongoing efforts. We believe these efforts can substantially improve elementary and secondary science and mathematics education over the long term.

This is the rationale for our Statewide Systemic Initiative recently announced in conjunction with the National Governors' Association. NSF will work with the States to plan and design activities that only the States can implement to bring about major educational change. They will, quite appropriately, build on many of the NSF supported teacher training and curriculum development projects that are beginning to yield positive results. More importantly, the States Initiative has as its purpose catalyzing the systemic, comprehensive changes necessary for major improvements of the teaching and learning of science and mathematics at all educational levels. The program involves teachers, the business community, the State and local education entities, Federal research laboratories, as appropriate, and, in particular, the Eisenhower Program of the Department of Education.

Urban areas are a point of special attention, because of the heavy concentration of population, and of minorities in particular. Our success in the educational area in the future will be heavily influenced by our ability to make a positive impact in our urban schools.

It will, however, be up to the individual States to decide how they can best put together a meaningful reform effort, given the various factors that affect a particular State's education system. It should be emphasized that the general flexibility and lack of prescription attending the congressional authorization of NSF programs permits the implementation of this Statewide Systemic Initiative. This flexibility enables NSF to stimulate and encourage comprehensive and systemic reforms in strategic and innovative ways.

This strategy to effect fundamental change in education and human resources is also evidenced by our FY1991 proposal to initiate the Alliance for Minority Participation Program mentioned earlier. This program grew out of our realization that, despite the many efforts to improve participation of minorities in the Nation's science and technology enterprise, minorities remain severely underrepresented in science and engineering. A more strategic approach is needed to attract a significantly larger number of minorities into science and engineering.

However, no single institution, be it higher education, industry, or the private sector, is capable of addressing this problem alone. There is a need for a collaborative effort among all of these participants. This has led to NSF's Alliances program to support efforts that concentrate on increasing the number of undergraduate and graduate S&E degrees received by minority students by the formation of explicit partnerships between NSF and other sponsors (e.g., other Federal agencies, S&E industries, private foundations, higher education institutions).

The importance of cooperation pervades our programs at all levels. For example, industrial participation has also been a significant feature of the undergraduate and graduate educational programming at Engineering Research Centers and Science and Technology Centers, of the prestigious Presidential Young Investigator program, and of our Publishers' Initiative.

Cooperation within the Federal Government:

As is clear from the orientation of all NSF efforts in science and engineering education, cooperation between the Federal Government and universities, industry, the states, and local communities, is critical to the entire strategy. It is also an important objective within the Government, and among Federal agencies.

The National Science Foundation and the Department of Education have been working together to improve coordination. The purpose of these meetings is to identify specific agency strengths and responsibilities, recognize differences in our missions, programs, and relationships with other sectors of society, and focus on areas of mutual interest. In March, Dr. Allan Bromley, Assistant to the President for Science and Technology, sent to Congress a congressionally-mandated report on coordination between NSF and the Department of Education. That report also spells out a series of specific areas of formal coordination that we have established with the Education Department. On an informal level, Secretary Cavazos and I have joined with Dr. Bromley to pursue discussions on how NSF might assist the Department of Education in the reauthorization of its mathematics and science programs.

While NSF and the Department of Education have well established roles with respect to science and engineering education, other agencies have significant contributions to make as well. NASA and the Department of Energy are responding to the need for a comprehensive national effort in this area by increasing their focus on education. As Chairman of the Federal Coordinating Council on Science, Engineering, and Technology (FCCSET), Dr. Bromley has created a Committee on Human Resources and Education. The Committee, of which Admiral Watkins, the Secretary of Education is chairman, and Tel Sanders, Undersecretary of the Department of Education, and Luther Williams, NSF Senior Science Advisor, are vice-chairmen, will work to reduce program overlap, identify areas of need and develop a truly integrated inter-agency effort in the area of mathematics and science education.

Role of Congress:

Congress has been highly supportive of improving science and engineering education in this country and the consequences of this commitment are clearly visible in the strong increases in NSF support for education and human resources.

Congress can also contribute to this process by improving coordination among committees with oversight responsibilities for mathematics and science education, and by paying closer attention to the strengths of the respective agencies as the basis of their own programs and of cooperative activities. One of the most important contributions Congress can make is in the area of forbearance. As indicated earlier in this testimony, the Foundation's flexibility to innovate and to pursue excellence has been fundamental to the effectiveness of its programs and needs to be preserved.

Conclusion

NSF has a compelling responsibility to provide national leadership for developing a comprehensive strategy for precollege mathematics and science education in the U.S. To this end, the Foundation is supporting innovative approaches to stimulate the reforms needed across the entire educational spectrum. As NSF continues to provide strong and sustained leadership and continuous investments, we will work with other Federal agencies, the private sector and State and local governments to improve the quality and effectiveness of a nationwide educational effort. Our efforts at the precollege level show great potential, but in the end, it will be up to our State and local education entities to make the commitment and decisions necessary to incorporate the lessons learned through the efforts supported by the Foundation and others.

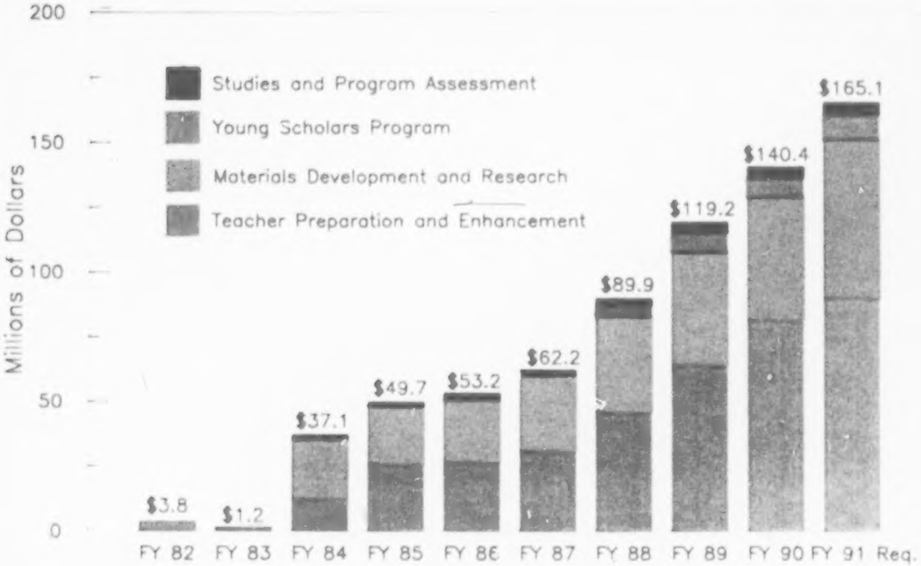
In this national effort, we will continue our role as sponsor and leader of effort to define national standards for local implementation for mathematics and science education for all students at all levels. This is not business as usual. In fact, many features of our programs are significant changes from the past -- but only where indicated and thoughtfully determined.

Thank you, mr. Chairman. I will be happy to answer any questions you may have.

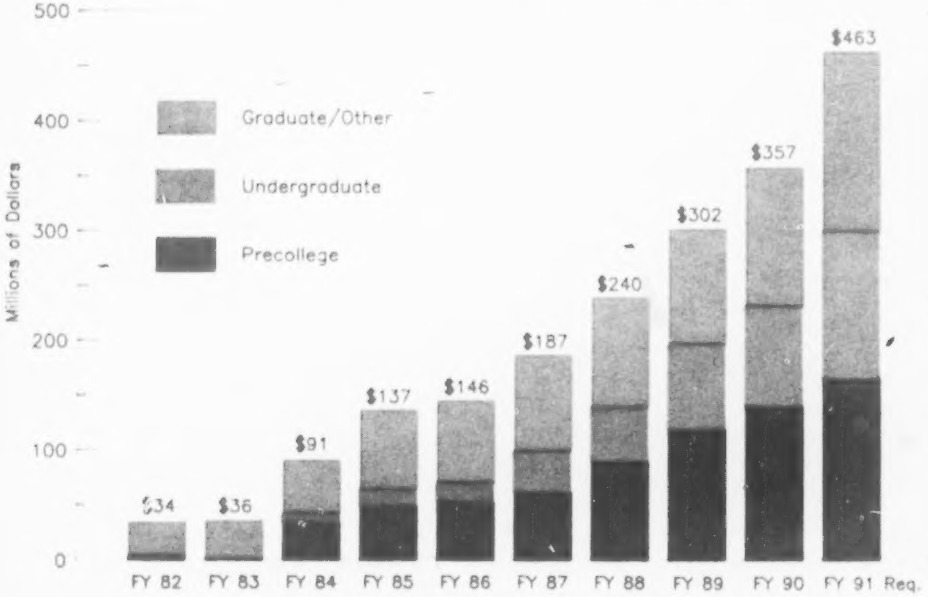
EDUCATION AND HUMAN RESOURCES THEME
(COMPONENTS)

Program	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90 PLAN	FY 91 REQ
PRECOLLEGE	49.7	53.2	62.2	89.9	119.2	140.4	165.1
UNDERGRADUATE	15.2	17.5	37.5	49.5	77.4	90.5	134.2
GRADUATE FELLOWSHIPS	27.3	26.1	27.3	30.3	24.0	29.2	35.9
PRESIDENTIAL YOUNG INVESTIGATORS	17.1	24.9	33.9	40.9	45.1	45.1	47.6
NEW INVESTIGATOR INITIATIVES					4.2	4.4	13.2
WOMEN/MINORITIES							
PROFESSORSHIPS FOR WOMEN	2.1	2.1	2.0	2.3	2.3	2.3	2.7
RESEARCH OPPORTUNITIES FOR WOMEN	2.6	2.0	2.5	2.6	2.9	3.2	3.5
FACULTY AWARDS-WOMEN							5.0
WOMEN IN ENGINEERING						0.7	1.5
MINORITY RESEARCH INITIATION	2.6	3.0	2.7	2.9	3.1	3.4	3.8
RESEARCH IN MINORITY INSTITUTIONS	5.0	5.0	5.0	5.0	5.0	4.8	5.0
Subtotal	12.3	12.1	12.2	12.8	13.3	14.4	21.5
EPSCoR	1.0	2.0	4.0	6.0	8.1	9.8	9.8
OTHER (GLOBAL CHANGE EDUCATION, RESEARCH TRAINING GROUPS, SPECIAL POSTDOCS, ETC.)	14.2	9.7	9.7	9.9	10.2	23.6	35.8
TOTAL EHR	$136.8	$145.5	$186.8	$239.3	$301.5	$357.4	$463.1
PERCENT OF NSF BUDGET	9.1%	10.0%	11.5%	13.9%	16.0%	17.2%	19.4%

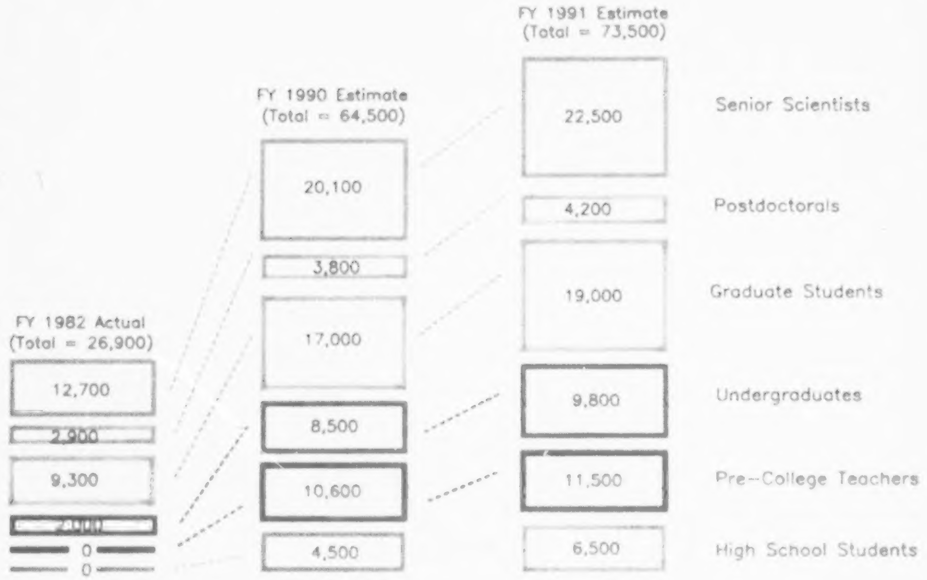
National Science Foundation
Precollege Activities, FY 1982 - FY 1991



National Science Foundation
Education and Human Resources



NATIONAL SCIENCE FOUNDATION SUPPORT FOR HUMAN RESOURCES



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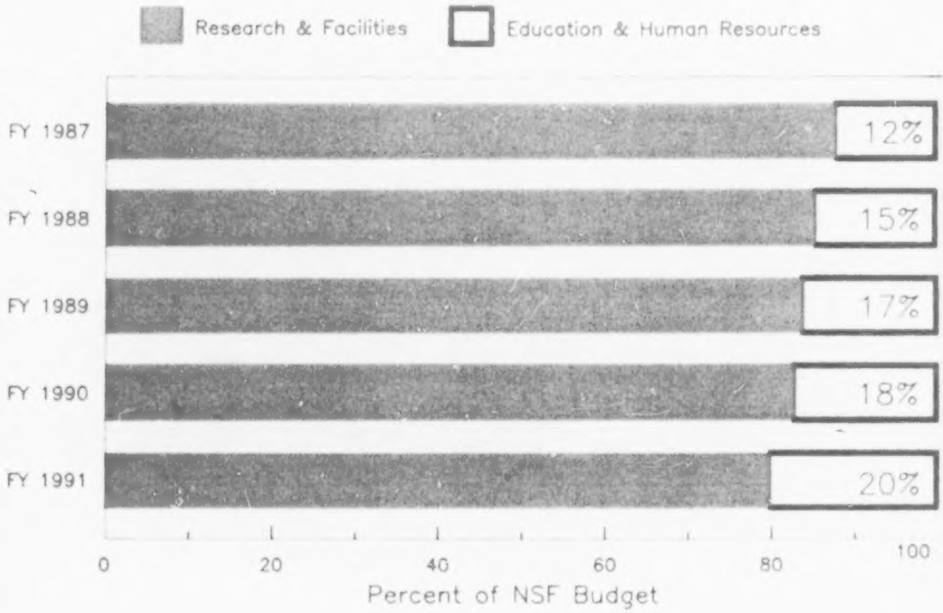
National Science Foundation
Major Themes Comparison



Senator GORE. Thank you very much for an excellent statement. It was very, very helpful.

And before I ask any questions I want to recognize my colleague, Senator Robb, for any remarks he wishes to make.

Senator ROBB. Thank you, Mr. Chairman. I am just here to listen. I am only going to be able to stay a few minutes, but I did want to hear Mr. Bloch's presentation, and I look forward to reviewing the testimony.

Senator GORE. Thank you very much, Senator Robb.

Mr. Bloch, how reliable are the projections of a shortfall of scientists and engineers? We sometimes hear things so frequently that we accept them as holy writ without looking beneath the veneer. Demographics and economics are not exact sciences, and manpower projections are notoriously difficult to make. Shortages of technical talent have been predicted before and sometimes have not materialized.

So, to ask the question a slightly different way, if you were a betting man, what kind of odds would you give that there will in fact be, without changes in current policy, a serious shortage of well-qualified scientists and engineers by the year 2000?

Mr. BLOCH. Two to one.

Senator GORE. Two to one.

Did you win on the derby last Saturday?

Mr. BLOCH. No, I do not bet on horses; I only bet on people.

Senator GORE. Okay.

Mr. BLOCH. Well, to seriously answer your question, that is obviously a great concern to everybody. Let me say at the outset that we have not tried to predict what the need is in the future, and especially not by disciplines. Because that is really a difficult thing to do, and if you do it you are mostly wrong.

The way we have tried to assess it is essentially by assuming that the production of scientists and engineers, undergraduate and graduate, is exactly the same in the future—not an increase and not a decrease—and the need for them is not an increase or a decrease, as it was in 1984, which we took as our base year. Because of the demographics and solely because of the demographics, namely the decline in the 22-year-old population, and with no change in the attraction rate of the people and the students going into science and engineering, that a shortfall would exist to the tune of roughly 675,000 people by the year 2000 or 2005.

Essentially, we did not attempt to predict the requirements. We predicted a steady requirement as it was in 1984.

Now I should also tell you that if you look at what has happened over the last five to eight years, in terms of the employment of scientists and engineers, you have seen a tremendous growth occurring. And the growth is, by the way, surprisingly enough, not only in the manufacturing industries and in government and in colleges and universities, but it is also in the service sector. In fact, the growth in the service sector is greater than the growth in the manufacturing sector.

The second thing that has happened, however, in the manufacturing sector, is that the percent of total employment of scientists and engineers has increased also. So you have seen two phenomenons. First of all, a major increase in scientists and engineers across the whole economy, and second, a higher concentration of scientists and engineers in sectors like the manufacturing sector.

So I think we have a conservative approach to it when we are saying we are going to be short 675,000 people.

Now the question that you can ask is, well, why do not we change the attraction rate in the number of people who pursue science and engineering degrees? And surprisingly enough, if you look back 20 years, that rate has been fairly constant. It has not moved up and it has not moved down. It has stayed about the same, at about the 4.5 percent level.

So that is one leverage that we have, that we can change that attraction rate, but that will not be very simple and that will not be very easy.

For that reason, we are focusing on under-represented groups, women, minorities and the disabled, that I mentioned before, because those groups have shown a lower attraction rate to science and engineering.

Senator GORE. All right. To summarize and paraphrase what you have said, you think we may be making conservative projections of this problem because the demand side is not adjusted to reflect what could be a dramatic increase in demand?

Mr. BLOCH. That is right. It assumes, essentially, that the demand side stays constant and does not go down either, but stays constant. And we have seen, not only in industry but in our total economy a higher demand for scientists and engineers because of the content of what people are dealing with in both the service sector and in the manufacturing sector.

Senator GORE. So, again, to summarize your response, you are pretty confident that this is an extremely serious problem and not just a projection that might turn out to be a false alarm?

Mr. BLOCH. Right.

If I may, Mr. Chairman, let me add one more point to it. If you look over the past 20 or 30 years you have seen at times a slackening off of the requirement. For instance, in the 1983–84 time frame you saw chemical engineers who could not find jobs with the decline in the natural resource industry, for instance. These temporary surpluses are being snapped up very quickly, however, over relatively few years. We saw the same in the 1960s.

And while there can be some temporary slackening off and disturbances, I think one has to really look at the total picture over a longer period of time, like five or 10 years, where really the requirements have always been on the increase and not on the decrease.

Senator GORE. Now one of the trends has been a dramatic increase in the percentage of foreign nationals receiving post-graduate degrees in science and engineering. And many welcomed the influx of talent. In fact, you yourself came to school here in the United States at the graduate level. What is your experience?

Mr. BLOCH. The undergraduate level.

Senator GORE. Because you were attracted by the excellence of our educational facilities, and I guess for a variety of reasons.

Mr. BLOCH. Yes, for a variety of reasons, including opportunity.

Senator GORE. Right. At that time, what percentage of your fellow students, so many years ago, originated from outside the United States?

Mr. BLOCH. I would say very few. I cannot give you a number, but I would say very few. By the way, it is so long ago that I do not remember, even if I had known it at one time. Very few, whereas today we are seeing a different picture.

By the way, let me make one particular point. At the undergraduate level we do not see a very big influx of foreign students. We are seeing it at the graduate level, where the influx is very high. A rough estimate at the undergraduate level is maybe 3 or 4 percent. As you know, in the science and engineering areas at the graduate level it is a very high percentage.

Senator GORE. What percentage is it now?

Mr. BLOCH. Well, it depends on the discipline, but in certain disciplines like engineering, it is a good 50 percent.

Senator GORE. Fifty percent.

Mr. BLOCH. In mathematics it is very high, interesting enough.

Senator GORE. What about computer science?

Mr. BLOCH. In computer science it is very high.

Senator GORE. What, 50 percent?

Mr. BLOCH. Well, it is close to 50 percent. I do not think it is over 50 percent, but it is close to 50 percent. It varies, obviously. A few years ago it was maybe even a little bit higher than it is today.

Senator GORE. Now of the foreign nationals who are being pulled in to fill this gap, what percentage of them receiving degrees decide to stay in the United States?

Mr. BLOCH. Right now, that is a large percent.

Senator GORE. It is about half, is it not?

Mr. BLOCH. It is about half, right. And again, it depends on the discipline. You know, it is different from discipline to discipline. But the ones that we are looking at are critical disciplines like mathematics, many of the engineering disciplines, and computer science, as you mentioned. It is close to 50 percent or sometimes even over 50 percent.

Senator GORE. Now, is it reasonable to suppose this trend will accelerate if there is, as you project, a growing mismatch between the demand for scientists and engineers and the supply being turned out by American educational institutions?

Mr. BLOCH. Well, I do not know if this trend will accelerate. Let me tell you what concerns me. While there could very well be that there will be an increasing number of students that come to the United States, I really am concerned if we see the retention rate that we are experiencing now to continue in the future as opportunities arise in their home countries.

Let me give you a couple examples. Taiwan has made the news of late for attracting back to Taiwan people who have for a long time been in the United States, either as students or after students as employees. One of my friends, a former vice president of Texas Instruments went back three or four years ago and is heading up one of the big semiconductor corporations in Taiwan. And he was here probably for a good 25, 30 years, employed at Texas Instruments and other places. So that is just one example.

But I am afraid that we are going to see that trend continue as Korea, Japan, Taiwan, and other countries, including European countries, by the way, build up their capabilities.

Senator GORE. Well, does the influx which seems to be growing still—I notice in this morning's paper, for example, there is an article about a surge of students from the Soviet Union—does this continuing influx indicate that the quality and health of university research and science education in the United States is still the best in the world and still able to provide the best education in science and engineering in the world?

Mr. BLOCH. Well, I think it definitely indicates that, and there is every reason to suspect that that is really the case. So, I think the quality of our higher education system is outstanding. My concern there is that our pre-college system is not as good as that, and that will take a toll at some future time in the quality of our total education system, higher education system included.

Senator GORE. This committee is keenly aware that while the health of our universities is good overall, we still have laboratory facilities and scientific equipment for labs that are outdated and falling apart and university professors too busy with research or reviewing research proposals to worry about teaching undergraduates. There is a long list of problems, but just speaking for myself, I am convinced that the more serious problems are the ones you just noted a moment ago.

When we look at the education pipeline, we tend to focus on the relatively few who make it all the way through, but we need to look at the much larger number of American students who leak out of that pipeline along the way.

What kind of science education prior to the college are the non-science students getting and what kind of science education are the undergraduates in college getting? How many are really graduating as scientifically literate and what does that mean? How much science does the average science need to know?

These are general questions, but I think you understand the basic thrust of them because the answers to those questions directly affect the number of students who choose careers in science and engineering.

Mr. BLOCH. Well, I think at the pre-college level our students should know a lot more than they know today about both science and mathematics. They should be much more exposed to science and mathematics than they are today, via longer hours and so forth. They should have more equipment available to themselves to experiment while they are in high school. They should be pulled into research activities while they are in high school to a greater extent than they are today, and that is why we have some programs in the Foundation to make that happen.

So I think it is an uneven situation, first of all. It varies from state to state, it varies from school to school. Some schools are very outstanding and some of them are very poor. So, it is essentially the uneven level that I think we need to be concerned about. So I think we need to bolster that.

At the undergraduate level, which you also asked for, I think our—and that is why we have been focusing a lot of attention on it in the Foundation—the quality of the undergraduate education in engineering certainly and in many of the sciences I think has deteriorated over time, and it is time to rejuvenate that.

Why has it deteriorated? Two things. First of all, a lack of—what you mentioned—lack of instrumentation is certainly one reason. Undergraduate laboratories are not state-of-the-art laboratories. Research laboratories are state-of-the-art laboratories. And, secondly, in the number of universities, by far not in all, I think undergraduate education has taken a back seat compared to research itself. So there are indications of the sort that we had better correct our ways.

Senator GORE. Well, the Office of Technology Assessment recently issued a report looking at science and engineering education from grade school all the way through graduate school and included a recommendation in its final report that NSF should take a stronger leadership role in science and engineering education.

Today science education programs exist at the Department of Education, the Department of Energy, NASA and other agencies. Is there a need—in spite of the numbers you presented in your opening statement, do you believe there is still a need to coordinate these different activities better and what do you see as NSF's role in perhaps providing some interagency coordination?

Mr. BLOCH. Yes, there is a need to coordinate these activities better and, by the way, Dr. Bromley agrees with that and—I mentioned it in my testimony—has set up a committee that spans all participating agencies on the issue of education and human resources. And I think that is a very important step, and I think all along over a period of time it will benefit this whole activity. First of all, by everybody being aware of what goes on and being able to join forces and resources in order to make these programs more effective. So I think that that will have a long-term effect, and I think we are moving in the right direction.

The Foundation's responsibility in science and mathematics and engineering education I think is one of leadership for the whole Federal Government.

Senator GORE. Admiral Watkins at DOE has promised to greatly expand the educational programs in his department and, as I mentioned earlier, several different agencies are involved in science education. Are there some which you think should play a greater role and is there some difficulty in having so many cooks in the kitchen?

Mr. BLOCH. Well, I am not so sure that there is any difficulty in having a number of agencies participating as long as there is the kind of a coordinating function that I mentioned before in place, which was not the case a year or two ago.

With regard to whether they should play a bigger role, yes, I think so. They should play a bigger role in it. NASA, for instance, and the Department of Energy, certainly should play a bigger role in pre-college education as well as in the support of graduate education.

I have been looking at NSF's graduate fellowship program. Between us and NIH—NIH for the life sciences and we in part for the life sciences, but primarily in the engineering and the natural and social sciences are about the only game in town when it comes to graduate fellowships. The rest is relatively small, and what we talked about before, attracting more American students to advanced degree levels depends very heavily on graduate fellowships.

Senator GORE. Well, let me just ask you point blank. If you had an extra $100 million for science and engineering education which is not earmarked—and I do not unfortunately have the check here this morning, but if you did—where would that money go? How much would go to research, how much to education, and of the amount to education how would you spend that money?

Mr. BLOCH. That is a difficult question to answer. If you had asked me about a billion dollars I might have been able to answer it easier than $100 million.

Senator GORE. We do not even have the check for $100 million.

Mr. BLOCH. I understand that.

What you are driving at is essentially the balance between research and education. Let me say one thing about it. Both of them are grossly underfunded, so that is where the problem starts. Realizing, however, what the situation is in 1990, I probably would put most of that money into educational programs and in research programs in order to bring these to a higher level.

By the way, it would not be just in one part of the educational pipeline but spread from graduate education to undergraduate education to precollege education.

Senator GORE. Let us say that you have $100 million which can be devoted entirely to education. How are you going to spend it? You just said you would spread it throughout the pipeline, but give us a little more of a feel for your intentions.

Mr. BLOCH. It would probably be a 50/50 split between precollege education and graduate fellowships. Not because undergraduate education is overfunded or even adequately funded, but I probably would leave out some of the undergraduate areas primarily because $100 million will not go very far if you split it three ways.

Senator GORE. Your Director for Science and Engineering Education, Bassam Shakhashiri, has said that NSF should be devoting at least $600 million to science and engineering education compared with the President's request for $250 million in fiscal year 1991.

Let us suppose that Dr. Shakhashiri's dream comes true. What kind of programs be able to fund that cannot be funded today, and what benefits could we expect from that increased expenditure?

Mr. BLOCH. Let me say first of all that Dr. Shakhashiri's comment can be duplicated by other assistant directors, those of mathematical and physical sciences, computer and information sciences, engineering and so forth always give you the same kind of a number, and for good reasons. These are not just numbers that are dreamed up, but it is deeply felt by the staff and by my colleagues that we are grossly underfunded. That is what you see. So the comment from Dr. Shakhashiri can be duplicated across the board many, many times.

Now coming to your question, if he had the $600 million I think his focus would probably be in doing more in those same areas where we are involved today: teacher preparation; materials development; addressing students; young scholars programs; and so forth. In all of these areas you can use more funding and more activities.

Certainly some of the newer programs, the State program that I mentioned in my remarks before, and the alliance programs, could use more dollars than we are able to put in now and, would then spread it across more states and across more institutions.

Senator GORE. Thank you.

Senator Robb.

Senator ROBB. Thank you, Mr. Chairman. I have to leave here in about two minutes.

First of all, a question you mentioned in your testimony, forbearance by Congress, I am not quite certain whether you were asking us to ease off on earmarking or had something else in mind in that comment.

Would you clarify that for me, please?

Mr. BLOCH. Yes. What I had in mind with the word "forbearance", which might be a bad word to use, was not so much earmarking, per se, but it was the prescriptive nature of some of the legislation that we are seeing coming down the pike.

Senator ROBB. Is there any particular legislation or any particular prescriptive language that you found particularly burdensome or onerous?

Mr. BLOCH. I will say all of them, to be very honest with you.

Let me characterize the National Science Foundation and its programs. Because of Congress we have a tremendous capability to move quickly into all kinds of areas where the benefits could be very great. We can move in there, getting the information from the people who are involved with the programs themselves, from the students, from the teachers and so forth. I think that helps us greatly in coming up with programs that have a big impact.

If you have to spend X dollars on a particular program for undergraduate fellowships and then have to chase after them to make sure that they pay back or if they do not pay back that they are complying with the requirement of teaching for two years after they graduate and so forth, we are really diluting our effort. It is not clear that this attracts the best people.

So, essentially, my use of the word "forbearance" meant to trust us to do the right thing. Now I know that is a big word. On the other hand, I do not think you can determine from up here what is the best program. We cannot determine it in the Foundation, either. Together with our clientele I think we can come a lot closer to a productive kind of a program.

Senator ROBB. Mr. Bloch, a purely personal question. You were talking about the undergraduate experience and fellowships, scholarships and what have you. Did you have a son that graduated about six years ago or is that a different person? Somebody with the same name who scored a 1600 came to my office while I was governor. I was going to ask you about his progress in science and engineering and to keep an eye on him.

Mr. BLOCH. No. Sorry.

Senator ROBB. Mr. Chairman, I am going to have to go bang the gavel and open the Senate here in three minutes. If you will please excuse me.

Thank you, Mr. Bloch.

Senator GORE. Sorry to ask questions myself for so long, Senator Robb. Thank you for your questions. I have only a few more before we will go to our panel.

After the education summit of governors last year—and you referred to that summit in your statement—President Bush set the goal by the year 2000 U.S. students will be first in the world in science and mathematics achievement. What does that mean? Is he talking about elementary school students, high school students, graduate students, all students or what? And how will we know if we have met this goal?

Mr. BLOCH. Well, I think what he was addressing was primarily the pre-college area.

Senator GORE. Pre-college?

Mr. BLOCH. That is my interpretation: elementary and high school.

Senator GORE. And how will we know if elementary and high school science and education has produced students here in the United States with the highest level of achievement in science and mathematics in the entire world?

Mr. BLOCH. Well, I think there are two criteria. The first one is, we regularly compare ourselves to other nations in the accomplishment of our students in science and mathematics. That is one way. But I think there is a second way which might be more important in the end, and that is if we see more interest in the sciences and engineering as expressed by students' course selection.

Many times today I do not think it is a lack of interest on the part of the individual students in pursuing science or engineering. I think the capabilities are not there to do it. At the time you come out of high school, and enter the university, it is a little bit late, you know, to decide I need more mathematics or I really should understand what science is all about. If you do not have that understanding and knowledge at that particular point, you are really left out or you are dealing with very great difficulties. So I think in that respect that is another criteria that we should keep in mind.

Senator GORE. Well, I am sure that the President was serious when he stated this goal and his intention to reach it. We have less than 10 years, and we have a very long way to go in order to meet that goal. Do we have a game plan? Have you seen any game plan for meeting this goal? Have you seen any estimates of the total cost of meeting this goal? is it going to be like the transportation policy where the President's role is confined only to articulating the goal and requesting that local and state taxpayers finance the meeting of the goal, or is this one going to be real?

Mr. BLOCH. Well, I hope it is going to be real, and I think it is going to be real. But the President—you know, the President's setting that goal is the important thing. You cannot and should not look to the President to tell you how we go from here to there.

Senator GORE. Why not?

Mr. BLOCH. Why not? I do not think that is his function. I think that is the function of the agencies.

Senator GORE. And so the President's role is merely to make meaningless and empty pronouncements?

Mr. BLOCH. No. Meaningful pronouncements is——

Senator GORE. Excuse me?

Mr. **Bloch**. Meaningful, not meaningless.

Senator **Gore**. Meaningful, full of what?

Mr. **Bloch**. Full of the goal itself and——

Senator **Gore**. But not the means for reaching the goal?

Mr. **Bloch**. Well, let me finish that. I think it is up to the agencies—and by the way when I say agencies, I do not mean just the Federal agencies, but the state and local agencies to really fill in underneath what that strategy is. We are working and have been working in the Foundation on a strategy for ourselves.

The FCCSET committee that I talked about before which is coordinating across the Federal Government, will have to take into consideration the individual inputs from the various agencies and make sure that the mosaic is the right mosaic and achieves the goal. Our involvement with the states, with the State Governors Association, I think is in that particular respect an attempt to pull them into this strategic plan. But I do not think you should ask of the President that he come up with the plan.

Senator **Gore**. Well, I do.

Otherwise, I do think it is meaningless and empty. It would be a little like announcing the goal to land a person on the surface of Mars and then saying that state and local government will have to figure out how to do that. It is different. It is different——

Mr. **Bloch**. I think it is very different, however.

Senator **Gore**.——with education.

Mr. **Bloch**. Okay with education——

Senator **Gore**. But if it is a national problem——

Mr. **Bloch**. It is a national problem——

Senator **Gore**.——when we set a national goal, then true leadership consists of more than simply stating the goal, grabbing the glory and then asking others to make the hard choices and offer the true leadership needed to reach the goal.

This is not your responsibility, Mr. Bloch. And you know my affection for you and admiration for your leadership. And if you could have the President do what he really should do on this question, I am sure that he would actually spell out some ways to reach the goal. But I will not put you on the spot here. I will wait until other occasions to do that.

Mr. **Bloch**. Okay.

Senator **Gore**. I just have a couple more questions, and then I want to recognize my colleague, Senator Kasten. First of all, the links between research funding and education, most of NSF's budget goes for research grants, and clearly if those grants can be more closely linked to the education and training of future scientists, there could be a big impact. We have been discussing the two categories of funding as if they were separate but there is, in fact, a significant overlap.

What portion of NSF's budget goes for research grants to individual investigators?

Mr. **Bloch**. To individual investigators it is about 65 percent.

Senator **Gore**. Sixty-five percent of the research budget?

Mr. **Bloch**. Of the research budget.

Senator **Gore**. Okay. Much of that money goes for research assistantships, stipends for graduate students doing research. Unfortunately that links a graduate student's compensation to funding for a particular professor's research project. If a grant does not get renewed, a student may have to scramble to find alternative support.

Is there any way to address this particular problem? Are there ways to restructure the distribution of NSF research funds to better link research to education?

Mr. BLOCH. Well, that has been a concern of ours, and there are a number of activities that we have started in order to make that linkage. First of all, a principal investigator who has a grant from the National Science Foundation can come back to the National Science Foundation and ask for a small amount of additional dollars, in order to use a high school student or even an undergraduate student in his laboratory for a period of time to introduce him to research and so forth. It is the REU program that allows you to do that.

Secondly, we have been also focusing on asking the individual investigator when he comes in with the grant request to tell us what effect that particular grant would have on education. I just sent a letter out last September to that effect to all universities, asking them to come forward with that kind of an information. It is a subtle way of essentially pointing out the need to focus on more than just graduate assistantships, but also on undergraduate students and pre-college students.

Senator GORE. All right.

Now, finally, in many American colleges and universities research and science education are, as we have noted, inextricably linked, and professors do serve a dual role, research and the teaching of graduate and undergraduate students. And research funding contributes directly to education because research grants pay some or all of many professors' salaries and provides stipends to graduate students, allowing them to pursue a master's degree or a Ph.D.

How important are these links? And is it possible to calculate how much of NSF's research funding is really going to fund the training of new scientists and engineers?

You gave us the figure of 65 percent in response to a different question. Is that the answer to this question also, or would you frame it differently?

Mr. BLOCH. No, I do not think that is the answer to this question. But let me give you—or refer you back to graph number three that I discussed with you, "Support for Human Resources." There you are essentially seeing what our total programs activity is doing with regard to supporting human resources. And you see on the top, senior scientists, you see post-docs, you see graduate students.

By the way, the majority of these graduate students are supported by individual grants. A small portion of that is the graduate fellowship program that I talked about before. But the majority of the 19,000 are being supported by individual grants.

The undergraduates are in part supported by undergraduate activities, and in part also supported by grants that go to individuals, or more importantly to centers and groups. The pre-college teachers and high school students are mostly supported by activities outside of the research area.

So that is probably a better indicator. And by the way, you see that we keep track of that from year to year to see what the effect of our increase in the budget is on these human resources.

Senator GORE. Thank you very much, Mr. Bloch.

Senator Kasten.

Senator KASTEN. Mr. Chairman, I do not have any questions or comments at this time.

Thank you.

Senator GORE. All right. Very good.

Before going to the next panel, I do want to say again how much I personally appreciate your leadership on these questions, and it was really in a conversation which you initiated that we began to develop this as a major priority area.

And I look forward—and I will say this on behalf of our subcommittee, I look forward to continuing our close working relationship with you and your team at NSF to develop better ways to address this problem. And I hope you will not hesitate to let us know of further recommendations as you continue focusing attention on this area.

Thank you very much for coming today.

Mr. BLOCH. Thank you very much, Mr. Chairman, for your interest.

Senator GORE. Thank you.

And now our panel of witnesses is invited to come forward. Dr. Richard C. Atkinson, Chairman and Retiring President of the AAAS, and Chancellor at the University of California at San Diego; Dr. Donna Shalala, Chancellor of the University of Wisconsin at Madison; and Dr. Alvin Trivelpiece, Director of the Oak Ridge National Laboratory in Oak Ridge, Tennessee.

And we are delighted that all three of you could be here today.

STATEMENT OF DR. RICHARD C. ATKINSON, CHAIRMAN AND RETIRING PRESIDENT, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, AND CHANCELLOR, UNIVERSITY OF CALIFORNIA AT SAN DIEGO, LA JOLLA, CA

Dr. ATKINSON. Mr. Gore, you would like me to keep my remarks to about five minutes or so; is that correct?

Senator GORE. If possible, that would be wonderful.

Dr. ATKINSON. You have given me a little leeway there.

Senator GORE. If you need a little more time than that, we can handle it.

Dr. ATKINSON. Let me begin by saying that this is not self-advertising but in this last issue of "Science" I have a long article in there entitled, "Supply and Demand for Scientists and Engineers, a National Crisis in the Making", which I recommend to you. I go through a lot of the models and statistics that have been laid out. You talk about shortages both at the bachelor's level and at the Ph.D. level, some of that is spelled out in the testimony to which I am going to refer here.

I think it would be a mistake to take you through much of that in any detail. There are a few things, though, I would like to comment on.

First of all, when one talks about a shortage of scientists and engineers, all of these projections look to the future, and we are not expecting shortages in the early 1990s. We will not expect to see shortages, for example, at the Ph.D. level until the mid 1990s.

When they start to fall into place, however, they will be very, very large indeed.

So we have another five years where we are not going to be reading about dramatic shortages unless we are way off in some of these predictions.

The other thing I want to take note of, you made the remark in your opening statement about projections. In most scientific work, the word used is "predictions". One has a set of assumptions and then from that model of assumptions makes predictions. In this area we use the term "projection". It is a subtle difference, but it is to imply that these assumptions are all modifiable. The hope is that we will be able to intervene and modify the assumptions and, therefore, the projections will be modified.

You asked Mr. Bloch if he would make some estimates on the likelihood of these shortages. It is too complicated a question to ask, but I would be betting more like 100 to 1 that we are going to have dramatic shortages. Now we have to get down to the details of what those shortages would be.

Let me comment that there is one rule that I use, a mnemonic rule, which I think would be useful for you to keep in mind. It is what I call the 5 by 5 rule. What do I mean by that?

If you look at a slice of 22 years, a standard slice of the population we are going to look at, of all 22 years old in the United States 5 percent are expected to go on to get bachelor's degrees in science or engineering. It does not matter about going to college or the like; just take all 22 year olds, and 5 percent are expected to go on to get a bachelor's degree in science and engineering.

Then if you look at that pool who took bachelor's degrees in science and engineering, another 5 percent of those will eventually go on to get doctorate degrees in science and engineering.

Now by that, many will go on for advanced degrees in other fields, medicine or what have you. Of the 5 percent who took bachelor's degrees in science and engineering, another 5 percent will eventually go on to get Ph.D.s.

The issue then is how are those 5 percent going to hold up. Mr. Bloch pointed out that it has been remarkably constant over time. If you have a copy of my paper before you, you might just look at page 11a. That gives you the percent of 22 year olds who took degrees in science and engineering. You can see in 1960 it was around 4 percent. With the enthusiasm of computer science in the mid 1980s, it got up to a little over 5 percent. Next year it will be back down around 4.5 percent.

I said 5 percent in my 5 by 5 rule. I like to use that, but you have to judge that that is a little optimistic.

When you feed that all through in terms of the demographics, looking now at page 9a at a graph of the 22 year old population, when you feed that 5 by 5 rule through that process with a few other minor manipulations, then you come out with the flow of Ph.D.s that we can expect year by year as we go forward.

This is the last curve I will ask you to look at. If I can ask you to look at 13b, you will see what the supply of Ph.D.s will look like in the United States. That is taking account of certain assumptions about foreign students and what percent will stay in the United

States and so forth. Those are additional assumptions. If you have 13b in front of you, do you see the dash line? That is the supply.

Then the question is what is the demand going to be like? We can factor in a number of variables there. One is replacement variables. That is what I call the D1 demand curve. If we are going to replace the people in industry and in the universities who are retiring, then that is going to require a certain number of Ph.D.s. We know those numbers very well. We know what the retirement rates are in industry. So the D1 curve is really quite direct.

The D2 is an addition. It is looking at the increasing population of college students that we are going to expect in the late 1990s and early part of the next century. If we keep the same faculty-to-student teaching ratio, that gives you the D2 demand curve. Then the D3 curve is industry, the increases that are going to be required in industry.

Mr. Bloch made, I think, a very interesting point. In 1976 2.4 percent of the work force in the United States was science and technical in character. In 1986 it had grown to 3.6 percent. So we have an increasing percentage of our work force that is scientific and technical. This D3 curve that I provide I think is so conservative it is pathetic. I think that is an extremely conservative requirement for industry.

I am dishonest here. I am going one step further. If you will look at page 17a you will see the average shortfall in Ph.D.s that we are going to expect in the United States. On average, we are going to be producing about 11,000 per year for the work force, and we are going to have a shortfall of about 10,000. So it is a serious problem.

Let me comment. There are thousands of intervention measures to discuss. You have mentioned many this morning. I talk about some in my article. There is only one that I want to talk about now. We have to mount a graduate fellowship program much like we did after Sputnik.

Now again I am violating my rule, but I want you to look at page 21a. That represents the number of fellowships and research assistantships and the like that the Federal Government supported in 1969 and what we support in 1989. If you will look at the dashed section, in 1969 we supported 60,000 fellowships and traineeships Federally funded for science and engineering. Today we support about 12,000 Federally funded fellowships for science and engineering. We offset it a little by an increase in the number of research assistantships, but the level of support for fellowship training is a real problem.

I think we have to face this immediately. I have told you that that shortfalls will not begin to occur until the mid 1990s. I think this year we should mount a fellowship program. The minimal level should be at least 3,000 additional fellowships per year.

I am finishing now very quickly.

We should have 3,000 fellowships per year at the graduate level for science and engineering. They should be for a four-year period. They should be at the level of 25,000 apiece, 16,000 for a stipend for students, 9,000 to the university to cover the educational costs.

If you take the 3,000 per year for a four-year period and you get this into steady state, it is going to cost $300 million a year. I think it would be a program very comparable to the National Defense

Education Act Program we had after Sputnik. 300 million would be just touching the surface. It would fall far short of what is needed, but I think it needs to be done now and should be in the President's next budget.

Thank you, Mr. Chairman.

[The charts referred to follow:]

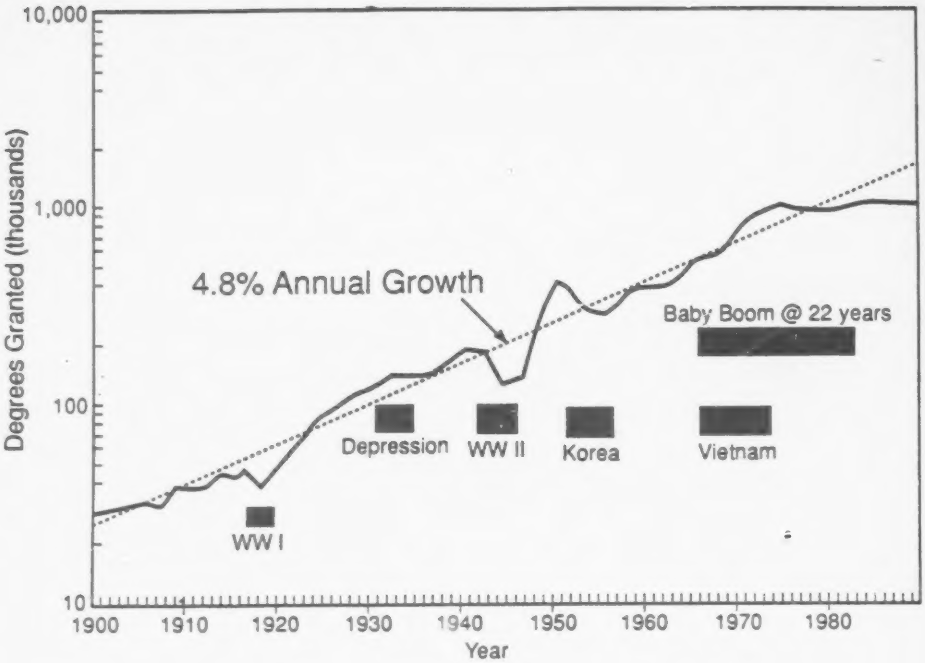


Figure 1. Growth of U.S. bachelor's and first professional degrees from 1900 to 1988.
Source: National Science Foundation.

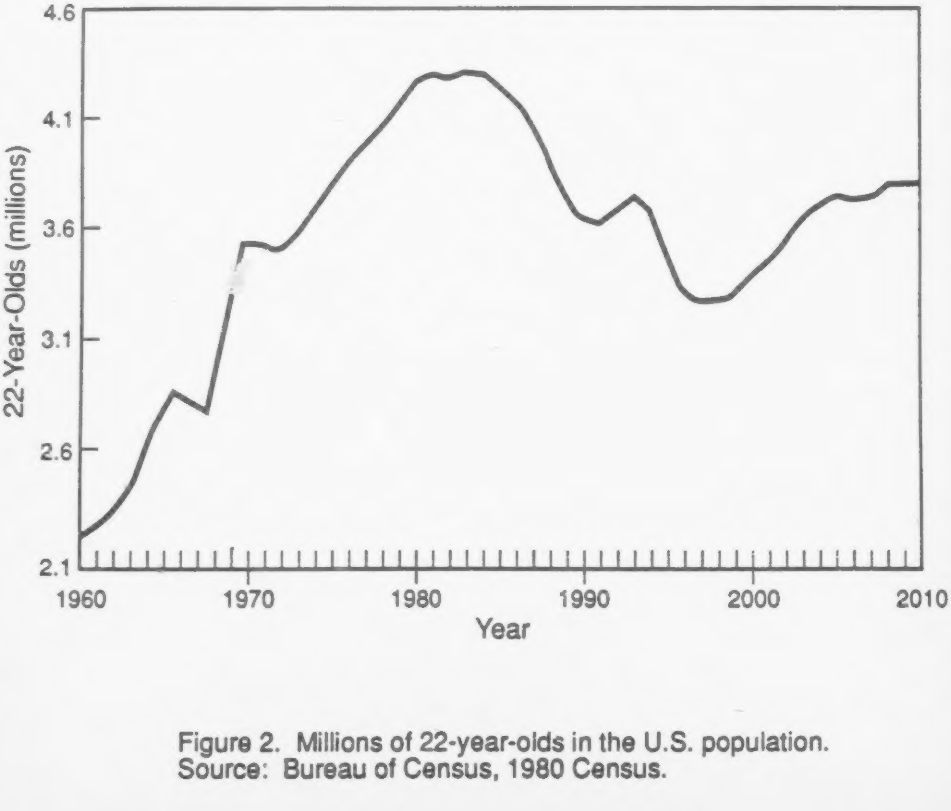


Figure 2. Millions of 22-year-olds in the U.S. population.
Source: Bureau of Census, 1980 Census.

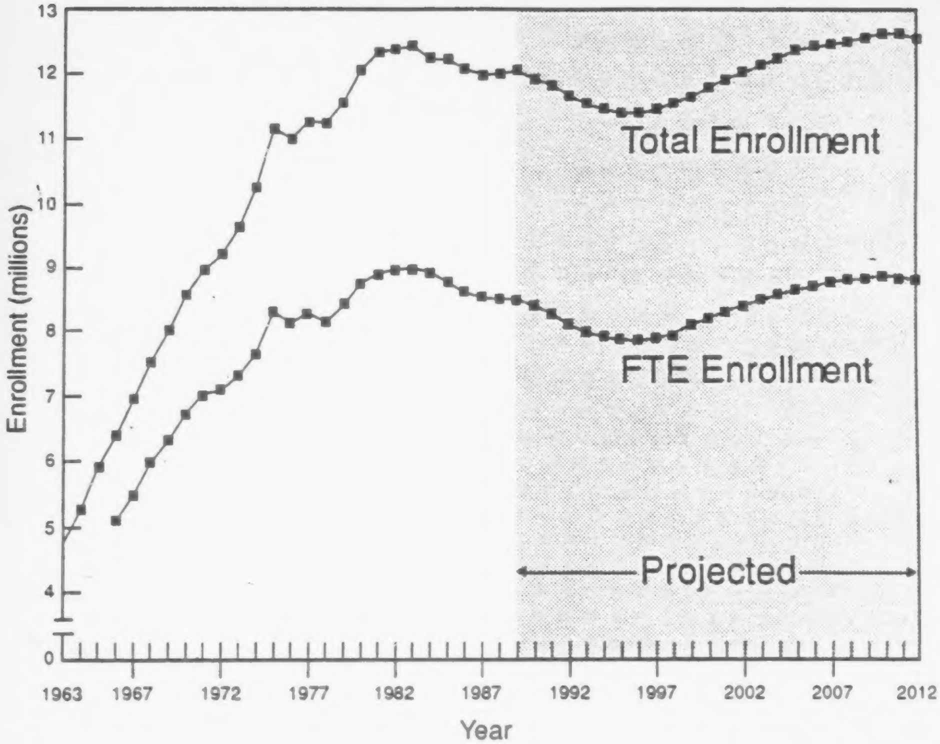


Figure 3. College enrollment trends and projections from 1963 to 2012. Separate curves are presented for total enrollment (full-time plus part-time students) and full-time equivalent (FTE) enrollment.
Source: Bower and Sosa.

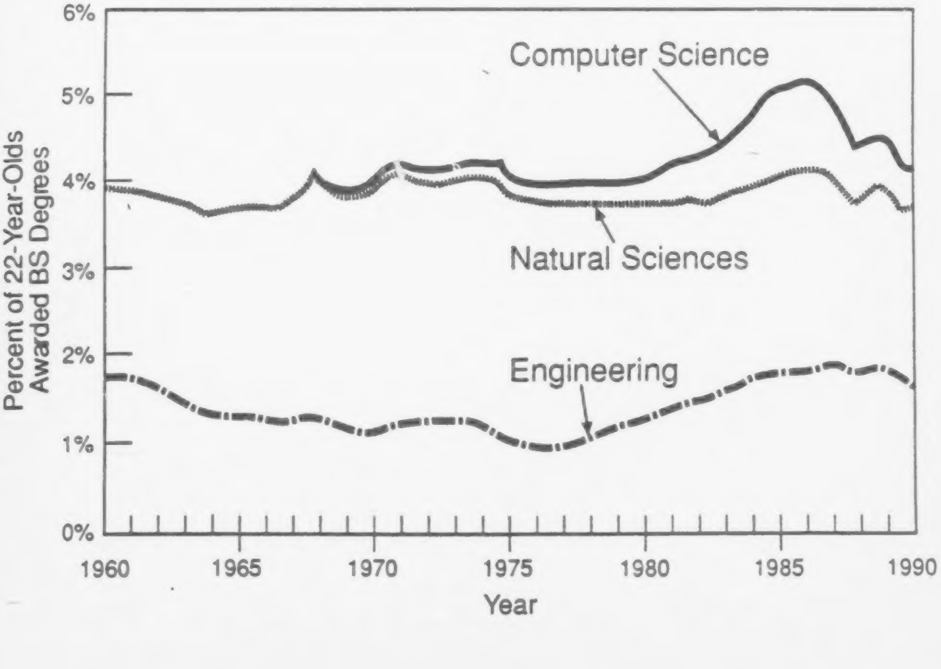


Figure 4. Percent of 22-year-olds awarded B.S. degrees in the natural sciences and engineering.
Source: National Science Foundation.

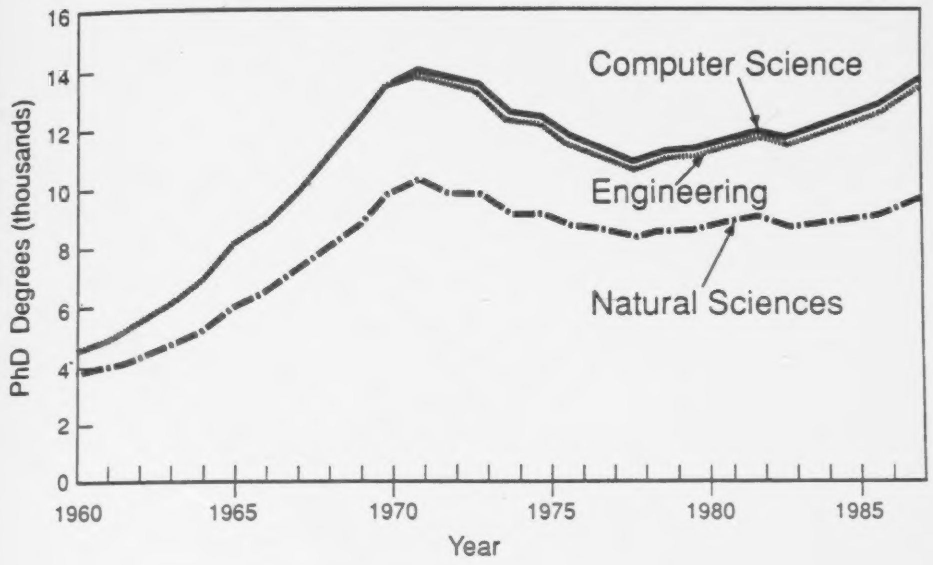


Figure 5. Number of PhD degrees in the natural sciences and engineering from 1960 to 1987. In 1987, production rates returned to the peak rate of 1971.
Source: National Science Foundation.

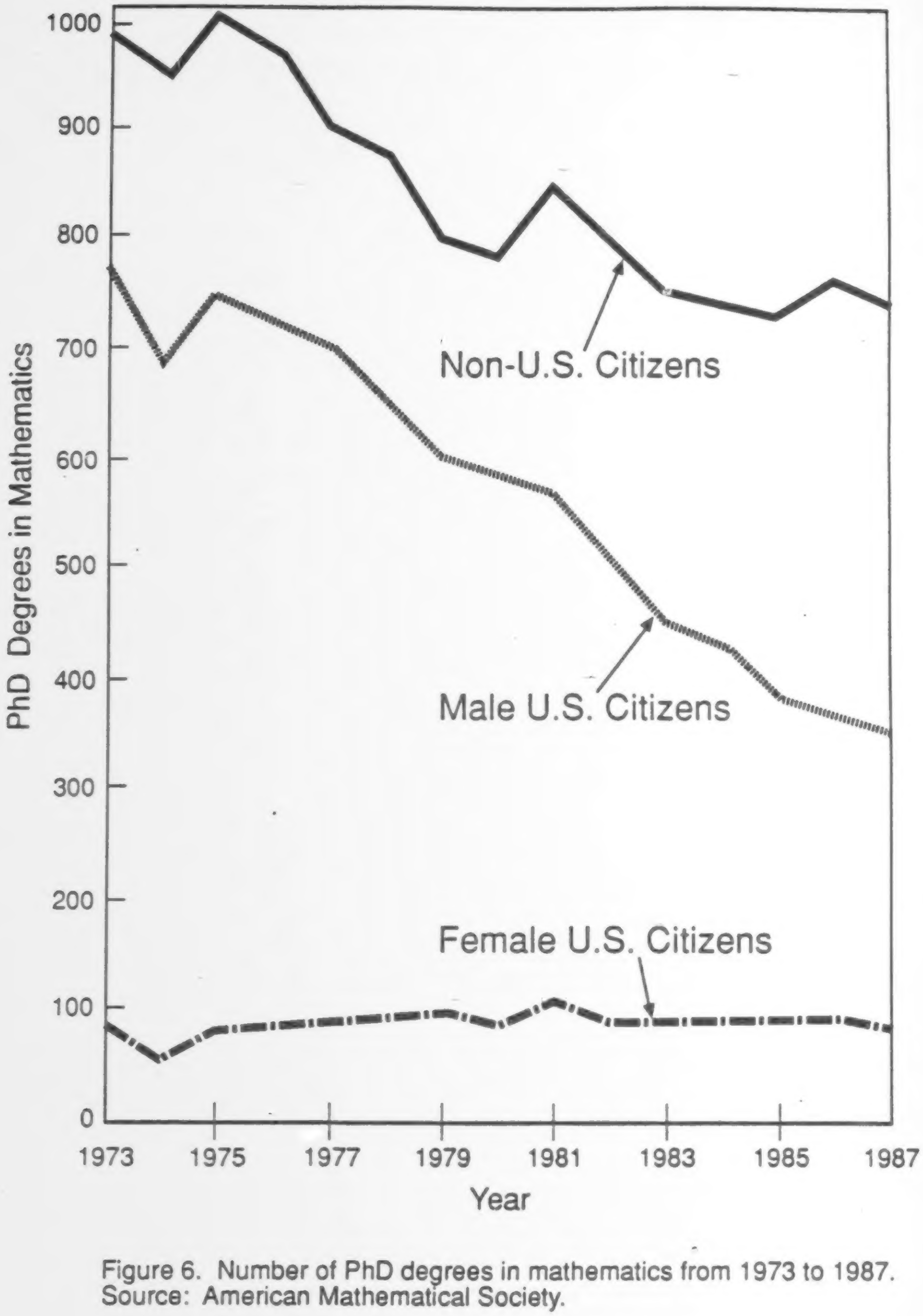


Figure 6. Number of PhD degrees in mathematics from 1973 to 1987.
Source: American Mathematical Society.

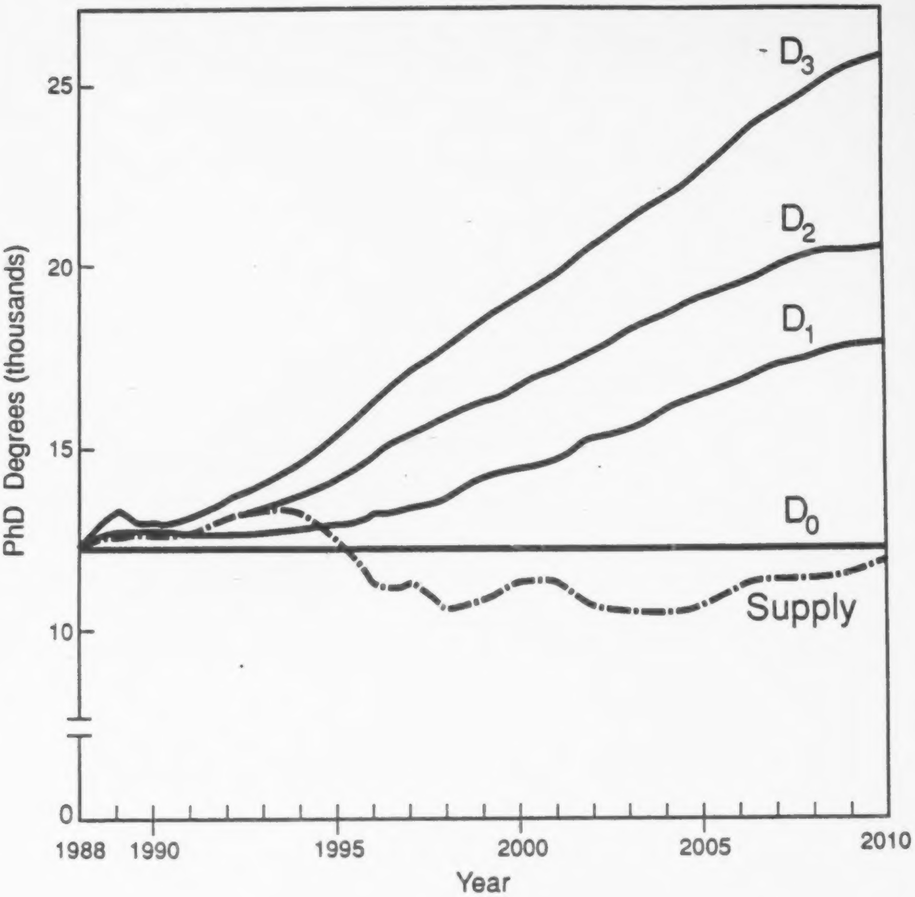


Figure 7. Supply and demand projected to the year 2010 for PhDs in the natural sciences and engineering.

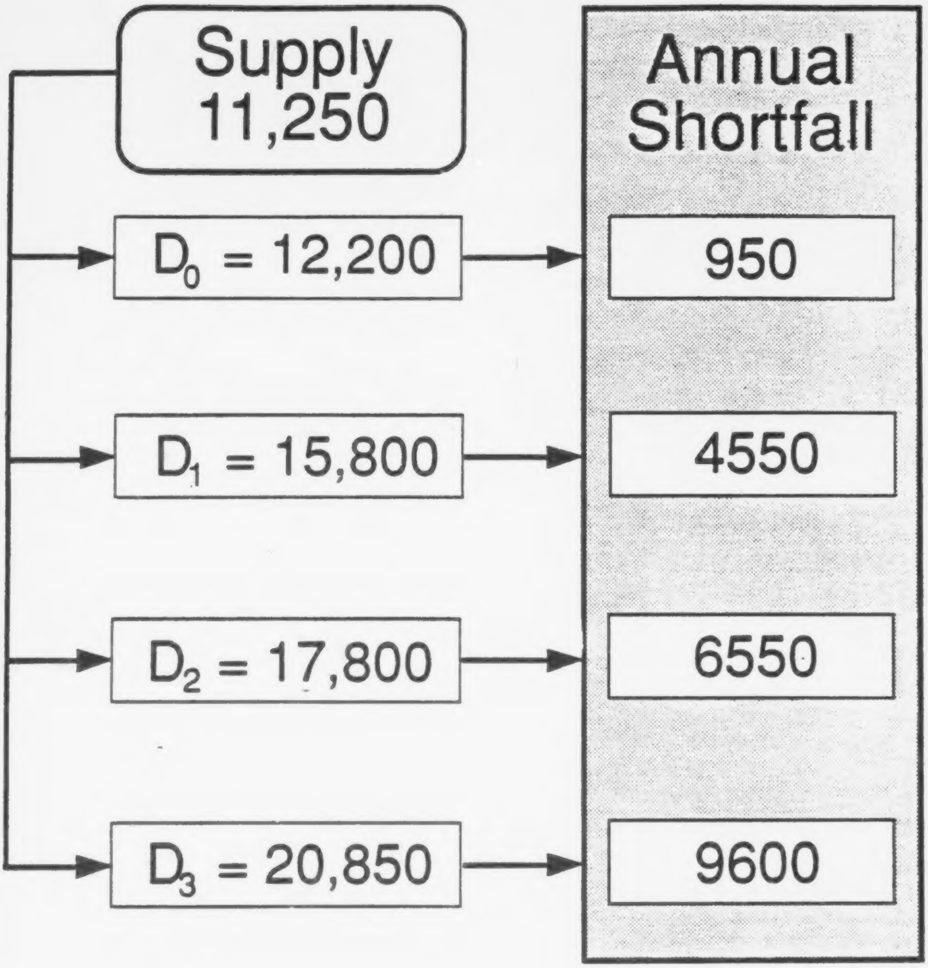

Supply
11,250
D_0 = 12,200
D_1 = 15,800
D_2 = 17,800
D_3 = 20,850
Annual
Shortfall
950
4550
6550
9600

Figure 8. The annual supply and demand for new PhDs in the natural sciences and engineering averaged over the 16-year period from 1995 to 2020.

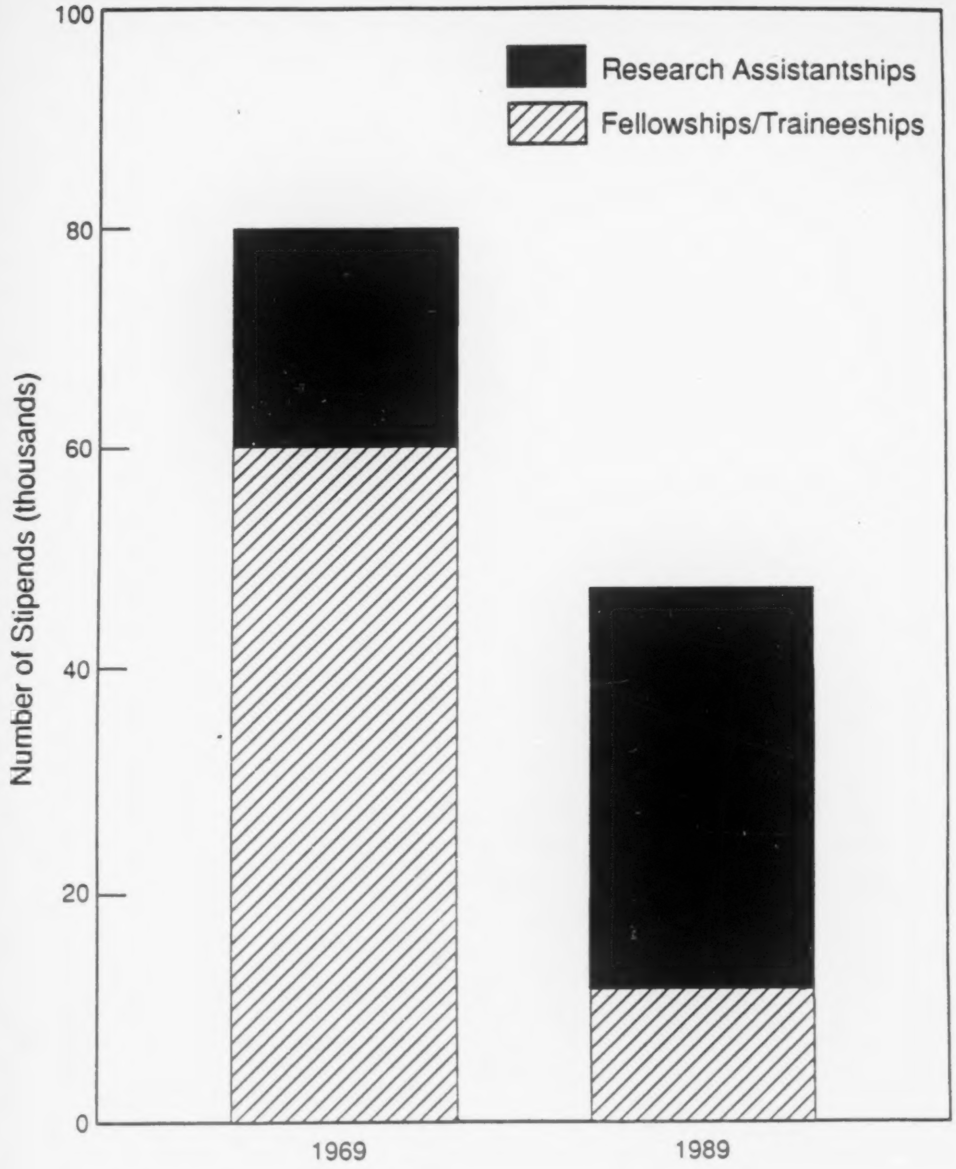


Figure 9. Federally supported student stipends at the doctoral level.

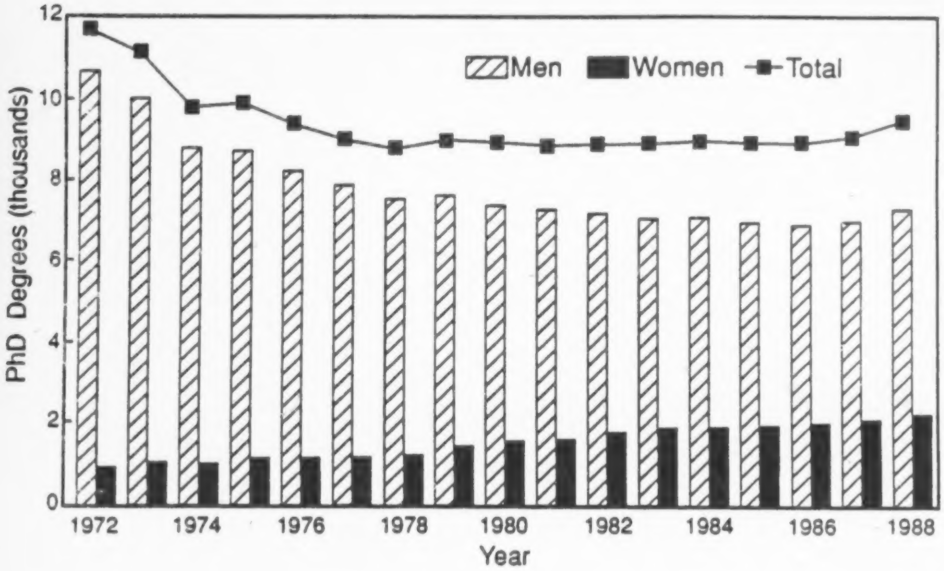


Figure 10. Number of PhD degrees awarded to U.S. citizens (men and women) in the natural sciences and engineering from 1972 to 1988. Source: National Science Foundation.

Senator GORE. Thank you very much. And I commend to my colleagues your full text as well. It is very thorough and well prepared.

Our second witness on this panel is Dr. Donna Shalala.

Senator PRESSLER. Mr. Chairman, could I just put a statement in the record?

Senator GORE. Yes. Excuse me, Senator Pressler, I should have recognized you before I moved on to the second witness.

Senator PRESSLER. I am doing the committee waltz this morning, and I am going to listen and read very closely what our fine witnesses have submitted.

Senator GORE. Dr. Shalala is Chancellor of the University of Wisconsin at Madison. And Senator Kasten has already bragged on you, Dr. Shalala. Let me say my mother went to law school at your institution in the 1930s, and so we are glad to have you here.

Please proceed with a summary of your prepared statement.

STATEMENT OF DONNA E. SHALALA, CHANCELLOR, UNIVERSITY OF WISCONSIN AT MADISON, WI

Dr. SHALALA. Thank you very much, Senator Gore. And I want to thank Senator Kasten for his kind words and his long support of the university.

I think maybe what I can do that is useful, because my two colleagues here as well as Erich Bloch have outlined some of the stats on the kind of crisis that we are facing, is to talk about the pipeline problem from the perspective of someone who heads a major research university.

Because I am concerned that in looking for places to intervene we might focus our attention just on the pre-college level. Because if we put in a block of money at the pre-college level and then had an increase in the number of students interested in science bounce through to the undergraduate level and did not have the kind of facilities and teachers that we needed at that level, we would not produce the numbers that we need at the graduate level and the Ph.D. level.

And it really is a pipeline, a pipeline that needs support from the beginning right through the end, and even when you get at the end and produce that Ph.D., as Dick will tell you, the start-up costs for new faculty, the level of facilities that they need so that they can complete the tenure process in about a six-year period are enormous.

And I know that the University of California system has the same problem that we have at the University of Wisconsin, and that is facing large numbers in the mid-1990s of new faculty that have to be started out. These are tremendous costs for every university in this country.

So it is the pipeline that we need to keep in mind.

Like everyone else here, I would certainly like to attract more women and minorities. That will take a tremendous infusion of money for facilities, not only in the great research universities, but I should point out as a trustee of Spellman College, the great black women's college in Georgia, about a third of our students at Spellman are interested in the sciences and they need stronger facilities at a historic black college as well as our other universities if we are going to produce both women and minority students coming out at the end ready for graduate support.

Just a couple of points about graduate and training grants, and I think that Erich made the point very well, but I sure would like to make the case, that while the statistics show, and it certainly is true at Madison, we have had a decline in the number of fellowships and traineeships and an increase in the number of students that we are supporting on research grants, we get tremendous support from NSF and NIH. This year we have 878 students on fellowships and traineeships and 2,645 supported on research grants.

I would not separate the training of students from the research grants. I believe that this is the clinical experience of enormously talented future scientists.

And just to give you a real-world experience, in recent weeks all of us have turned our attention to the Hubble space telescope and the really tremendous scientific potential of that telescope. The University of Wisconsin built part of that machine.

We had 100 graduate and undergraduate students who were actively involved in the construction and in the development of the high-speed photometer, which was one of the six scientific instruments aboard the space telescope. And it was a research program that financed those students. And their roles ranged from the design of the photometers aperture plates to the development of the software codes.

So that when we talk about a research project, we should not think that we are not training students as part of that research project. In fact, the American research university has integrated the training of undergraduates as well as graduate students in our large-scale grants.

So we are deeply concerned when NSF is not fully funded or when NIH, as it has recently, makes a decision to begin to fund only a portion of the research grant requested. Because that often cuts out some students that we are going to train as part of that project.

So there really is, in the research university, an interrelationship between the training of undergraduates as well as graduate students. You cannot walk into a major lab at the University of Wisconsin without seeing undergraduates there.

So that with all the beating up that we are taking, some of it appropriate, about what we are doing about undergraduates in research universities, it is undergraduates and graduate students that are being trained in our great research universities as part of these grants. Often they are hourly employees, but more often than not they are part of the team that is getting trained, and it is a way in which we turn on undergraduates.

Finally, let me say something about women and minorities and the opportunity to attract them. We have a crisis situation in terms of who is going to do science and technology in this country. One way of filling some of that gap is to increase the number of women and minorities that are active.

But it should not only be an argument to fill the gap, it has to be an argument that we have to have full participation. We are leaving out part of our scientific brain power if we do not pull in large numbers of women and minorities into our future training grants.

And I support Dick Atkinson's call for a larger number of fellowship support. I would hope that some of them are in fact set aside for women and minorities so that we can increase those numbers. I also would be willing to take up a challenge from the Congress to match some of that money with private gifts and with state support.

We happen to come from a state, the Senator and I, in which the state has been a tremendous supporter of graduate fellowships for minorities and poor students. And I know that in our state, and also the private sector that we deal with and the foundations, would be willing to provide some of the match for some of that money.

And I think you ought to give us that challenge and I think that working with the Congress and with the other universities we really could make some impact on the training of a new generation of women and minorities in the sciences and in technology.

Thank you very much.

[The statement follows:]

DONNA SHALALA

CHANCELLOR, UNIVERSITY OF WISCONSIN-MADISON

TESTIMONY

U.S. SENATE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

MAY 8, 1990

Mr. Chairman, I appreciate the opportunity to appear today before the Subcommittee on Science, Technology, and Space of the Senate Committee on Commerce, Science and Transportation. I would like to present the perspective of a major research institution on what actions are necessary to avert or at least ameliorate a major crisis in the supply of scientists and engineers for the next decade.

It's simply this: We must attract more of our young people into scientific careers, particularly those minorities and young women who have been traditionally underrepresented in scientific professions, engineering and technology. We must further provide support and opportunities to ensure that we do not discourage and lose future scientists and engineers. And we must be ready to facilitate the establishment of the professional careers of those students whom we have trained.

NATURE OF THE PROBLEM

Much has been said and written by my colleagues, including my distinguished co-panelists Dr. Bloch and Dr. Atkinson, concerning the shortfall of scientists and engineers this country is predicted to face by the year 2000. You have already heard an outline of the dimensions of what has commonly been referred to as the "pipeline problem." I shall not dwell further upon this problem except to give you a feeling for what this can imply in terms of the anticipated needs of a major research institution. This is an analysis of the sort of hiring which will be required at the University of Wisconsin-Madison in the next decade in order to maintain the University's position as a premier center of research in the sciences and engineering. As one of the leading research and teaching institutions of this country, the University of Wisconsin-Madison's situation reflects many of the circumstances which numerous other institutions of higher education are facing currently or will face during the next decade.

We're certainly very concerned, not only about our ability to compete, for students and for jobs, in a global marketplace, but about how such lack of preparation and underemployment will affect our lives in this country. This is not just a problem for higher education or for industry but for society as a whole.

First, let me address the impending turnover in faculty that is before us. Not unlike colleges and universities across this country, the UW-Madison will face massive retirements in the next decade unlike anything we have ever experienced. The numbers from an employer's and administrator's perspective are intimidating. If we compare the relative ages of the UW-Madison faculty in 1976 with the ages of the faculty in 1988, the problem becomes apparent. In 1976, the university had 725 faculty members who were 51 years of age or older. By 1988, that number had increased by more than 35% to 981. It should be noted that during this time the total number of faculty at the institution increased by only 53 positions out of a total of 2398 such faculty, indicating that the above numbers are a reflection of the aging of the faculty and not due to a significant change in the size of the faculty. Viewed another way, we are now projecting that the UW-Madison will experience 66 faculty retirements in the year 2000 as compared to the 39 which were experienced in 1988-89, an almost 70% increase. These numbers reflect the reality that the demand to fill these positions will arrive in this decade as predicted.

Next is the issue of how the removal in the 1990's of the federal mandatory retirement age of 70 will affect this demand. I think the Wisconsin experience can be of particular value here. The State Legislature removed such a mandatory retirement cap for our faculty in 1984 and Wisconsin has been "uncapped" longer than any other state. A review of our retirement numbers reveals that this option holds little hope for alleviating the pressure we will feel in the years ahead. While the distribution of retirement age has changed since the removal of the mandatory retirement age, the average age has remained relatively unchanged. For example, in 1976-77, the average retirement age on the Madison campus was 64.1 years. In 1987-88, that age had remained virtually unchanged and was at 65.0 years. Based on the data, removal of the mandatory retirement age will have little effect on the personal preferences of faculty to leave the university work force as they age.

However, past experience indicates that we will lose faculty to other institutions or professions at a rate which is about 1.5 times the retirement rate. While most of these are not lost to the total science worker pool, neither can they be counted upon as a gain for other institutions. In addition, the costs of establishing new laboratories apply also to this enhanced number of new recruits.

Finally, I would like to share some information from Wisconsin concerning the supply side of this equation. As you may know, the University of Wisconsin-Madison is one of the top 40 doctorate-granting institutions in the country. In fact, in 1988, we were second in the nation with 682 Ph.D.'s granted. This represented 2% of the total number of Ph.D.'s granted that year for the entire country. Wisconsin has been, and will continue to be, a major supplier in this increasingly tight market. Unfortunately, while national numbers reflect some increase in the production of Ph.D.'s, Wisconsin's contribution has been virtually unchanged during the past 12 years. In 1977-78, we contributed 665 doctorates to the national pool. Last year, that number was 689, an increase of only 24. Although we do not have detailed information on the distribution between U.S. and international students, it is clear that in some areas of engineering and science the fraction of non-U.S. citizens receiving Ph.D. degrees is increasing. The fraction of non-U.S. Ph.D.'s in our university as a whole may not have changed significantly. We are truly an international university.

In summary, let me state that the Wisconsin experience reinforces what my colleagues have said and are saying. A significant increase in faculty retirements will occur in this decade and early in the next, and for which we currently are not producing the graduates to fill those vacant positions. I can assure you that we regard this as a critical situation. As both a utilizer and a source of talent in these areas, it is crucial that we have access to the resources needed to address this problem.

STEPS TO A SOLUTION: PRE-COLLEGE

It should be clear that there are no magic solutions to this problem. Instead, we must plot a course which considers each step of the development and training of scientists and engineers, ensure that we provide for maximum access by all members of our society to enter upon this training, and guarantee that prospective scholars are not lost to these disciplines through a lack of available resources.

Simple demographic analyses demonstrate that our richest resource for new numbers of scientists and technologists will be minorities and women for the next generation. They will be the largest pool to draw scholars, teachers and professionals from in all areas as well.

We need to make sure that at the very beginnings of life, we give these young minds the nurturing they need. Later, we must invest in ways to transmit the delight and excitement of science and the possibilities for careers in this field, so that it becomes real to young students - no matter how difficult their backgrounds or school experiences have been.

Various studies have indicated that as children, many students have an original interest in the sciences; but this interest seems to be lost at various stages in the pre-college years for women and minorities. At the University of Wisconsin-Madison we are involved in a number of efforts to maintain or re-awaken interest in scientific or engineering careers in our young people.

Among these efforts is our "College for Kids" program, which brings together middle-school students during the summer to expose them to scholarly activities in a variety of fields. Although not specifically targeted to minorities or women, by acquainting these groups with the excitement of science, we hope to encourage their participation later on in its demands and rewards. Our Engineering Summer Program is specifically targeted at providing minority high school students with experience in all aspects of the engineering profession.

We must make sure that children from disadvantaged backgrounds, particularly, don't slip into a netherworld of indecision after primary school. It's in elementary school and middle school that these students are deciding who they will be; and we want them to know that the fields of science and technology are not closed to them. These doors are open to their approach, and when they do approach, we must be there waiting for them with peer counseling, tutoring support and a general atmosphere of support and encouragement.

Another facet of the shortfall problem is the difficulty of providing adequate pre-college instruction in the sciences. At the UW-Madison, we have made significant strides toward improving the teaching of science in the nation's elementary and high schools. The Institute for Chemical Education, founded at Wisconsin and now established at five other universities around the country, has provided workshops aimed at improving methods of science teaching for 1600 teachers so far. This program, funded by the National Science Foundation, has been a catalyst for the improved teaching of chemistry in hundreds of schools. It is catalytic in nature because the program helps draw state and local support to the fight against scientific illiteracy.

The Institute for Chemical Education is also now in the forefront of the effort to help funnel an increasing number of blacks and hispanics into the science and engineering pipeline. Institute centers at Washington's Catholic University and the University of California at Berkeley have established two-year training programs for teachers at elementary and high schools that have significant minority enrollments.

The goal of these programs is to empower teachers by giving them new skills and knowledge in both science and pedagogy to vastly improve the teaching of chemistry. The hope of these programs is to put more minorities on the science and engineering track. Again, this type of activity is in our own best interest.

In the years to come, higher education will need the elementary and high school students of today to assume leadership roles in the scientific enterprise.

Our Center for Biology Education, among other activities, supports various educational outreach programs and summer enrichment programs for minority students. The Center for Education Research and the Human Genetics Education Center play similar roles.

UNDERGRADUATE AND GRADUATE EDUCATION

I would now like to turn to the next stage in the pipeline, that is, the training at the undergraduate and graduate levels of future scientists and engineers. In order to prepare these young people for future careers at the cutting edge of technology, it is essential that we make available to them, in addition to modern instruction in their fields, both research opportunities as well as support for their studies. We must recognize that we can no longer afford the luxury of regarding college education, and in particular science training, as a privilege for students from upper or middle-class families. This is especially true when we are considering people from those groups not traditionally represented in the scientific work force. The shortage in prospective students in these areas makes it critical that we not lose (hence waste) this raw material due to an inability on the behalf of these students to finance their own college educations.

A variety of scholarship and loan programs have been created at the undergraduate level to help meet these needs. I would point out, however, that programs which result in large debt loads for students upon graduation may be counter-productive in creating an adequate reservoir of Ph.D. scientists and engineers.

If you had scraped together all you had to attend college, and learned that your debt was going to outpace your ability to earn before you even attained your majority, the temptation to surrender to despair would be strong. Grants, rather than loans, especially in the early years of college, might hold off the incursion of debt until a student is better able emotionally and economically to deal with that kind of burden.

Simple economic considerations too, can result in students electing, after completing the baccalaureate degree, to enter the market place rather than to pursue graduate studies toward a Ph.D. This problem has been particularly acute in engineering, for example, where in the past industrial demand has seriously depleted the ranks of those students going on to graduate degrees. In those cases the nation has justifiably been accused of "eating its seed corn."

It is common to think of financial support for students solely in terms of fellowships and, at the undergraduate level, loan programs. I would remind you, however, that research projects, such as those supported by the National Science Foundation, as well as other agencies, provide the major source of student support at the graduate level. Many of these programs provide appreciable amounts of support for undergraduates as well. For example, at the University of Wisconsin-Madison, in the fall of 1989, 878 graduate students were supported on fellowships or NIH traineeships, while 2645 graduate students were appointed as research or project assistants on research grants. Over the past decade the number of students supported by fellowships or traineeships actually has declined by about 10% (from 981 in 1980), while the number on research and project assistantships has risen by 20% (from 2227 in 1980). We do not have available comparable statistics for the support of undergraduates, but I can assure you that a significant fraction of those in the natural sciences and engineering receive are employed as hourly help or undergraduate assistants on our research projects.

A case study of a single project may help illustrate this point. In recent weeks, the nation's attention has been focused on the Hubble Space Telescope and the awesome scientific potential it harbors. One aspect of the space telescope, however, which has escaped public notice is the significant role the telescope has played in the scientific training of Wisconsin students. The University of Wisconsin-Madison is the only university in the nation to actually have constructed a part of this magnificent machine. More than 100 of our graduate and undergraduate students were actively involved in the construction and development of the High Speed Photometer, one of the six scientific instruments aboard the Space Telescope.

Under the aegis of this program--a research program--these

Wisconsin students were able to perform tasks ranging from the design of the photometer's aperture plates to the development of critical software codes. I can think of no better example than this of the important dual role that research dollars play in the meaningful education of future scientists and engineers.

Providing student support through the mechanism of research grants and contracts helps meet our second requirement for these students, namely, giving them access to research experience at the frontiers of knowledge. We regard this experience as an integral component of the education of a scientist or engineer. This sort of support therefore accomplishes three tasks at the same time. It provides support for the student, it provides training and familiarity with modern research techniques, and it contributes in an essential fashion to the actual accomplishment of that research.

A word of caution is in order here. If research grants and contracts are to form effective sources of student support and training, the lifetime of these grants and contracts must be sufficiently long to permit reasonable planning and completion of research projects by the students. Great progress has been made in recent years in avoiding the yo-yo effect of one year funding cycles, which provide support only to remove it once the student begins his/her training and research. The shift to longer-term grants has been identified as part of the reason for a crisis in funding, especially in the biomedical sciences. The crisis is real; the solution must not be to shorten the periods of grants.

It is of course possible to combine this sort of support and research experience with fellowship assistance. At the University of Wisconsin-Madison we have an extensive program of state-supported Advanced Opportunity Fellowships, designed to assist minorities and other disadvantaged groups to pursue graduate education. In the development of proposals for large center-type grants, such as the NSF Engineering Research Centers and the Science and Technology Centers, the institution is required to provide a substantial amount of cost-sharing in the budget for these centers. We have adopted a policy of providing some of that cost sharing by setting aside one or two of these Advanced Opportunity Fellowships for qualified minorities involved in the activities of the center. This provides a powerful incentive for the faculty and staff who comprise the center to recruit and work with minorities. Such a process integrates these individuals into the scientific activities in a highly effective way. We are committed to such efforts as part of the Madison Plan. This use of fellowships as part of the cost-sharing requirement is an efficient way of accomplishing our goals.

Thus far we have focussed upon the problems of encouraging adequate numbers of students to embark upon careers in science and technology, and in providing support and research opportunities for those students. We also have the task of integrating these students, once trained, into our pool of mature scientists and engineers. This is, if you will, the point where the pipeline enters the reservoir.

Some of these students will go on to jobs in industrial and government laboratories. It is necessary to recognize that the proper role of the university is to provide the general background, training and experience for these students. We cannot provide the detailed sort of on-the-job training which is specific to each particular job or industry. Despite our limitations in terms of training for specific jobs, those of our students who go on to industry provide our most effective method of technology transfer. The surest and most effective way to transfer the progress of our university scientific laboratories to industry and the market place is through the students whom we train, students who then go on to positions in industry.

Experience has shown that a large fraction of our Ph.D. recipients in the sciences and engineering will go on to positions in academia, in turn training future generations. Some of these students will go directly from the Ph.D. to faculty positions. An increasing fraction, however, will assume postdoctoral positions for one or more years to hone their skills and complete their preparation for life as independent scholars.

In either case, once they have assumed faculty positions, these individuals are under severe time pressures. They must, in sequence, establish laboratories, establish a research program, and establish a research reputation, all in the traditional six years before a decision on tenure is made at almost all American universities. This in turn means that we as institutions must be able to provide the laboratories and the state-of-the-art equipment which these young faculty need to be competitive in today's sciences. Problems with the state of the infrastructure at our universities have been extensively documented. The situation with respect to young faculty is especially critical, however. Due to their own time constraints, they cannot afford to wait for long-term programs or programs the effects of which will be delayed from year to year. In terms of our metaphor, the pipeline does not end until the research career is fully established. The universities, and indeed the nation, cannot afford the loss of talented individuals simply because we cannot provide them with the final tools needed for their final step.

BUDGET IMPLICATIONS

The picture which I have set forth regarding the encouragement, support, training and integration into the work force of new scientists and engineers has a number of budget implications, especially for granting agencies such as the National Science Foundation.

While I understand that there is increasing pressure to share the budget responsibilities with states and private industry, I would like to comment briefly on this direction. Due to the nature of graduate education and the mobility of the graduates, it is very difficult to get state governments or industrial leaders to invest invest substantially in this area. Because their return on investment is so unpredictable, we cannot hold much hope in receiving extensive financial support from these sources. Graduate schools and graduate students are truly a national resource and are, therefore, a legitimate federal responsibility.

The obvious needs for pre-college programs have been largely recognized and already form a significant part of the Foundation's budget for education. At the undergraduate, and especially the graduate level, commendable steps have recently been take to increase the numbers and stipends of various fellowship programs. The situation is less optimistic when we look at support through either traditional few-investigator research grants or through large-scale centers. In this area the Foundation's budget has not grown dramatically, and as a consequence it has not been able to provide the level of funding in individual grants necessary to permit the full utilization of the present supply of graduate students in the science and engineering areas.

Considerable debate now exists in the scientific community regarding the relative utility of large center-type grants, and the traditional individual investigator awards. It is our position that both are needed. The center grants can provide core support for activities of related projects more effectively than a large number of individual grants can, but the awards for separate projects enhance the peer review, and hence the overall quality of the research done. The tension could be largely eliminated if the budget would grow to a level to permit a reasonable funding of both types.

I would like to comment upon an especially pernicious effect of only partial funding of proposals, or "downward negotiating" in the NIH terminology. When this sort of partial funding occurs, one of the first budget items to be removed frequently is the support for graduate students. In this sense there is a differential adverse impact on the support of students produced by this sort of budget cutting. A simple calculation indicates that a research program outside the laboratory sciences requires at least $50,000 per year in order to support two months of summer salary for a not-too-highly paid professor and a graduate student. When laboratory research is involved, the price tag increases substantially. Consideration should be given to establishing minimum level of awards, to help ensure the adequate support both for the research and for the students.

Finally, a full integration into the professoriate of the Ph.D.s whom we have trained will require a major infusion of funds for updated equipment and facilities. States and private endowments can provide some help, but they cannot solve the problem alone. Major amounts of federal money are required, and as indicated, cannot be long delayed if we are to avoid a major waste of our human resources. In one sense this is our most important investment in the future.

In summary, I would argue that we must be careful not to devote all our attention to only one part of the pipeline. We need to encourage more students to consider scientific careers, we must provide them with appropriate training and support, and we must give them the environment they need to fully function as our new generation of scientists and engineers. The greatest tragedy of all would be to encourage minorities and women to embark upon science and engineering careers and then not have available the support and research opportunities at the graduate level, or worst of all, not have available the tools to become mature established scientists.

Senator GORE. Thank you very much, Dr. Shalala. We appreciate that. We will hold questions until the panel has concluded.

It is a great personal pleasure for me to introduce the final witness on our panel. Dr. Alvin W. Trivelpiece is Director of the Oak Ridge National Laboratory and is someone who has long experience in a variety of different positions in looking at the question we are exploring here today.

We are proud to have you here, Dr. Trivelpiece. Please proceed.

STATEMENT OF DR. ALVIN W. TRIVELPIECE, DIRECTOR, OAK RIDGE NATIONAL LABORATORY, MARTIN MARIETTA ENERGY SYSTEMS, OAK RIDGE, TN

Dr. TRIVELPIECE. Thank you, Mr. Chairman and Members of the subcommittee. It is really a pleasure to be here. I think this is an important subject, and I appreciate the opportunity to talk about it a little bit.

The world is really quite complex technically. It is becoming more complex all the time. By the year 2000 it is going to even be more so. The last few decades we have seen some rather interesting inventions and discoveries. Lasers and supercomputers have been developed. High temperature superconductivity has been discovered. Fiber optics has played an enormous role in the technology of our Nation. We have a lot of problems out there of various sorts. If you pick just energy alone, you have the problem of nuclear power, carbon dioxide, acid rain, solar and things like that.

If you look at agriculture, it is scientifically intensive although not normally recognized as such. What happens to soils when plants deplete particular elements? How do you replace them? What will genetic engineering do? Can you really develop plants that will live on brackish water, fix their own nitrogen, produce their own herbicides and make their own insecticides internally, naturally? It is an interesting possibility, and it is quite controversial as to whether or not that can happen.

People talk about the computer revolution being here. I do not think the computer revolution has even arrived yet. It is going to be here one of these days, and I think this high performance computing initiative which you are taking a personal hand in, Senator Gore, is a very important one. Competitiveness comes up all the time. What do you do about robotics and materials? There are also a large collection of things in manufacturing sciences. There are new materials such as nickel aluminides that need to be looked into and have something done.

One of the things I look at as a key to this is mathematics. I believe that of all the subject areas that you can emphasize, mathematics is the key to all of it through all the educational levels. It is that belief that created a weakness in my armor. When I was asked if I would serve as the chairman of the math sciences education board I said yes. I did not realize what kind of a time-consuming extracurricular activity that it was going to turn into.

Just last week I was here in Washington for a meeting of about 500 education leaders on making mathematics work for minorities. This was an important conference, and it did stress the fact that mathematics is the key. There are many organizations that are trying to do something about bringing mathematics into the schools, and one of the keys is teachers.

I think in looking at facilities such as national laboratories, they have been an underutilized facility in that kind of an activity. We do now bring many teachers into the laboratory, high school teachers, for summer programs, and I believe anything that can be done to augment that kind of an activity is important.

About 20,000 high school students in the last five years have had an opportunity to go through the ecological and physical sciences study committee activities at the laboratory. They go through some 22 different programs. I think that this type of activity helps provide a basis for giving youngsters the belief that there is something to do that is interesting in science.

One of the problems we have, of course, in this country is that if you ask third graders to draw a picture of a scientist, you would not want to be the kind of individual that those pictures represent. They are usually bad looking people doing bad things to other people or animals or the environment.

Where does that come from? Is it television? I do not mean to bad mouth television——

Senator GORE. Oh, go ahead.

Dr. TRIVELPIECE.—but there are certainly many programs which probably do not create an image that is favorable toward pursuing careers in science on the part of youngsters. I think it would be important to try to do something about that.

As a former government employee having testified here many times, I did not realize the difficulties I caused for those that followed me, since the government witness is usually the leadoff witness. They get to state all the statistics, and then everybody else bats cleanup. Having a last name that is toward the tail end of the alphabet, I am usually the last witness on a panel, so I get to comment on what my colleagues said before me.

In that regard, I would like to comment on what Dick Atkinson said with regard to fellowships. He is right on the mark.

There is perhaps one element, however, that he left out. Although he was very explicit about the amount of money that is there, I think it is important that the analysis that should take place. When I was going through graduate school the ratio of what you could earn with your B.S. in hand and what you could get as a fellowship was about 2 to 1. In other words, you could earn twice as much as you were getting in your stipend.

That ratio today is 5 to 1 or 4 to 1. That has a tremendous influence on an undergraduate making a decision, shall I go on to graduate school or not, because even if they can get a fellowship, if that fellowship is only 20 percent of what they can get with their B.S. in hand, they quickly do the arithmetic to realize that no matter how entertaining the work they might do is or how much freedom it provides them. They will never again see that as a financial benefit.

In other words, getting a Ph.D. in my time was a financial benefit if you lived long enough. I do not think that today's undergraduate, looking at that and doing the arithmetic, can believe honestly that they will ever get it back in their lifetime. So the fellowships really need to be tailored to trying to bring that ratio somewhere in the 2 or 3 to 1 category. Otherwise, in spite of all good intentions, it may not help as much as you would hope.

With that, Mr. Chairman, I will be glad to turn to questions.

[The statement follows:]

TESTIMONY
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE
May 8, 1990

Alvin W. Trivelpiece
Oak Ridge National Laboratory

Mr. Chairman and Members of the Subcommittee, I am pleased to have the opportunity to testify before this Subcommittee to present my views on training of scientists and engineers for the year 2000. I look forward to this appearance because the topic of training our nation's scientists and engineers is clearly one of critical importance to our competitive posture. This is also an area in which I have had a long-term personal commitment having spent much of my adult life involved in science education. For nearly twenty years, I taught at the university level; while at the American Association for the Advancement of Science, I was actively involved in a broad range of educational activities. Now, as director of Oak Ridge National Laboratory, I have a vital interest in a highly qualified scientific and technical workforce. Finally, as chairman of the Mathematical Sciences Education Board, I am working to build a consensus for a national strategy of mathematics education. My testimony will provide my perspective on the effects of a projected shortfall of scientists and engineers, and then comment on challenges faced by the university research community.

Many studies over the past several years have indicated that our country's changing demographic profile, under present conditions, will not produce enough scientists and engineers in the next two decades. White males have traditionally been the largest segment of the population in the science and engineering work force. But time marches on and they retire and leave the work force. The new entrants to the workforce will largely be composed of minorities, women, and immigrants. As new scientists are needed to replace them, other population groups will have to take their place. But it just isn't happening fast enough. We are heading for a shortfall that could exceed a half-million in twenty years.

Oak Ridge National Laboratory and the nation's other Department of Energy laboratories are, according to the Secretary of Energy, "home to some of the world's brightest and most innovative scientists and engineers. Their creative minds are a precious asset and will be encouraged not only to continue their basic research, but also to improve the process by which new technologies are transferred to American industries, small businesses, and universities." Historically, our involvement in education has been focused in higher education with emphasis on research appointments at the faculty and postdoctoral level. Eventually, undergraduate programs were developed which also focused on research opportunities for students. Educational links between the laboratories and the academic institutions are seen as beneficial to both in that faculty, staff scientists, and students have access to research facilities that may not be available at the base institution and contribute to the ongoing research at that guest facility. Faculty, students, and the staff scientists interact with professional personnel beyond that of the base institution. Students that participate in the research programs provide an experienced set of hands and a pool of capable students to be encouraged to pursue graduate degrees or to consider employment at the national laboratories. These arrangements are attractive to the Laboratory.

I believe it is the national laboratories are key players in America's efforts to improve its scientific competitiveness. Our emphasis on fundamental research requires advanced degrees: over 50% of ORNL's research staff have doctoral degrees. We recruit across the nation for our professional and research staff and rely on local markets for other job categories. We are now feeling the effect of the shortfall in selected areas. Environmental and chemical engineers and materials scientists with advanced degrees are in short supply. I attribute this to the significant financial opportunities available to people with a bachelor's degree. There is little incentive to attend graduate school and obtain a doctorate when you can earn almost as much, and start earning it five years earlier, entering the workforce after your senior year. The shortage is also severe in other disciplines. The nationwide emphasis on radiation protection and industrial hygiene places qualified individuals with these backgrounds in great demand. Health physicists are essential for our work with radiation sources and we constantly searching the marketplace for individuals that are the very best in this field. Yet during a recent survey of ORNL, we had to request support from other

DOE facilities for the loan of several health physicists. Recruitment in some disciplines is difficult, and hiring qualified women and minorities, the logical source of new scientists and engineers, is even tougher.

In the years ahead, it is easy to predict that the competition for the top graduates will increase. As in most bidding wars, the wealthy and prestigious institutions will be the winners and the losers will be the other research centers. Unless alternatives are found to increase the number of qualified graduates, there will be fewer of them in industry, research, and education. Our nation's immediate competitive position, as represented by industrial needs, will suffer. Our long-term growth prospects will also suffer, as represented by education and research. If fewer scientists and engineers are on the staff of universities, future growth of qualified personnel will not be easily accommodated.

If Department of Energy facilities continue under their present budgetary stringencies, I am not sure of the extent of the immediate impact of the decline in availability of scientists and engineers because I am not sure the full effect would be felt at ORNL. This past year we narrowly avoided a layoff of scientists because of unanticipated costs associated with waste management. ORNL was able to transfer these scientists from their specialities to other areas where increased staff levels could be used. The Laboratory's overhead rate has risen dramatically to cover increased environmental charges that were not anticipated in the budget.

Budgetary considerations are affecting our competitiveness more than a shortage of scientific manpower. When we are in a state of declining research budgets,the cutting of research subcontracts is considered along with other options. ORNL currently has approximately $20 million of subcontracts and procurements with 100 universities. While ORNL values these connections, we recognize there may be little alternative to our actions. Increased budgets for research will allow the university-laboratory connection to be expanded.

In a 1988 study, the Department of Energy's Energy Research Advisory Board reported (Science and Engineering Education, report DOE/S--0065) on the Department's role in meeting its future manpower needs. The Board found that the Department has a continuing, critical requirement for a broad spectrum of highly educated and trained scientists, engineers, and technicians. They recommended that DOE continue and strengthen its role in the education and training of these human resources. In this context, the Board found that DOE has established a clear leadership role in graduate and postgraduate education in many fields of science and engineering related to its primary mission in energy research and development. They also found that this program makes a great contribution to other science-based, high- technology industries so vital to our nation's economic strength, and especially to our international competitiveness. The Board further noted that DOE's greatest contribution to science and engineering education is in supporting research in the universities, and in bringing the university professors and students into close working relationship with the DOE laboratories and energy-industry professionals.

ORNL and the Department of Energy have a strong commitment to science education and educational outreach activities that will impact the supply of the future technological workforce. About 1,000 college and university students and faculty from throughout the nation visit ORNL annually. In addition to university interactions a significant number of precollege participants also visit the Laboratory for various "hands-on" research experiences. During the past few years, ORNL's involvement and commitment to science education and educational outreach has continued to expand, and now is developing a plan for a Science Education Center. This plan, encompassing all facets of the DOE-supported University-Laboratory Cooperative Program, provides an integrated focus for program development at all levels from precollege (K-12) students and teachers through students at the undergraduate, graduate, and postdoctoral levels and college and university faculty. The document reflects new emphases and initiatives from the DOE-sponsored Math/Science Education Action Conference convened in October 1989 by Secretary Watkins in Berkeley, California. It also incorporates and expands the Laboratory's strong continuing emphasis on increasing opportunities in science, engineering, and mathematics for women and minorities as well as people with disabilities.

Two new proposals were recently developed to strengthen and provide greater continuity in the Science Education Center activity at ORNL. One of these initiatives would increase the opportunities for informal science instruction and for science and engineering career counseling available to young women of junior and senior high age. The second would fill a "gap" that exists in opportunities for young people to maintain contact with DOE laboratories during a critical period of their development. This is during the first two years of undergraduate study. It would provide a continuing avenue for summer research participation for students who, as secondary students, have participated in the DOE High School Science Honors Workshop, Project SEED, or special honors study opportunities and who later as college juniors and seniors will be candidates for the Science and Engineering Research Semester, Undergraduate Research Training, and Professional Internship programs.

The Department of Energy recognizes the important role that minorities have in the future competitiveness of the United States. To this end, ORNL continues to expand program interactions with Minority Educational Institutions (MEIs). The main thrust of the program is to develop opportunities through internal and external interactions. Internally the program emphasizes communication of Energy Systems' MEI program objectives; externally, attempts are made to encourage MEI participation in research through workshops, established contact networks, mutual visitations, and professional assistance. Program activities and initiatives are underway with a number of institutions toward the overall goal of increasing the number of scientists and engineers to help contribute to the manpower needs projected for the future.

The Memorandum of Understanding (MOU) with the University of Puerto Rico (UPR) established in FY 1988 continues to be a highlight toward increased interactions with Hispanic institutions. During FY 1989 this Memorandum provided a mechanism to support eight faculty and students to conduct research in various ORNL divisions. Also while subcontract activities are not funded through the Memorandum, subcontract activity through ORNL divisions also provides another mechanism for collaboration.

Also in FY 1989 as a part of the Historic Memorandum of Understanding and Intent, forming support for the DOE/OER Science and Technology Alliance, ORNL established a subcontract with North Carolina A&T State University (NCA&TSU). NCA&TSU, New Mexico Highlands University, and the Ana G. Mendez Educational Foundation along with ORNL, the Sandia and Los Alamos National Labs make up the Alliance whose intent is to develop a sustained program with the combined efforts of the participating institutions, to increase the representation of Blacks, American Indians and Hispanics in the scientific and engineering programs of the U.S. Department of Energy. ORNL established an initial subcontract with NCA&TSU in the amount of $372K for program administration, faculty development, student development, curricula development and other direct/indirect components as needed. While ORNL selected NCA&TSU as its prime contact, other activitgies will also be ongoing with the other Alliance Educational Institutions, which included assistance to New Mexico Highlands University in the establishment of an R&D library in support of a planned program in technology. ORNL will donate books and magazines totalling over $17K. Also, ORNL is assisting the Ana G. Mendez Educational Foundation in the establishment of a five-year plan for the Computer Center. ORNL is providing a staff member to consult with the Mendez Foundation in the creation of the operating plan for the Center.

Another component of the Historic Science and Technology Alliance is a collaboration between the ORNL Metals and Ceramics Division and NCA&TSU in the development of a sustained program, with the combined efforts of the participating groups, in the materials engineering programs of NCA&TSU. Interaction between NCA&TSU and the Metals and Ceramics Division dates back several years through collaborative research subcontracts totalling more than $1.5M. These research projects are credited with aiding several minority students to obtain graduate degrees in mechanical engineering. This collaboration has also led to the inclusion of NCA&TSU as a partner along with the Metals and Ceramics Division, the University of Dayton, and the National Bureau of Standards in a DOE-sponsored research program on the study of ceramic technology for advanced heat engines.

Efforts have been successful during the period to extend university subcontracts beyond the traditional ORNL R&D base. These efforts include interactions with Winston-Salem State University in mass communications, Coppin State College in contracts management, and North Carolina A&T State University in technical editing. This has proven particularly useful in support of institutions who don't have R&D capabilities to support DOE/ORNL missions. The total estimated dollars committed to Higher Education Institutions for the first half of FY 1990 is $8 million. The total commitments to MEIs for Energy Systems is $1 million which included $0.9M for ORNL.

ORNL is also a member of the National Consortium for Graduate Degrees for Minorities in Engineering (GEM). GEM is a consortium of universities and industry, both private and federally-formed, to help increase the pool of minorities receiving graduate degrees in engineering. GEM has a graduate rate of 86% of those who enroll in graduate school. ORNL will sponsor two graduate students in a semester research experience during FY 1990 and FY 1991.

By reaching teachers who are in daily contact with young students, it is possible to excite their interest in science at an early age. Students interest in science has been shown to drop during the latter portion of elementary school. Many are "turned off" by science at an even earlier age. Teachers must be a vital connection in any national program to increase the science and technology abilities of the United States.

The joint ORNL/Oak Ridge Associated Universities Project SMART (Science/Math Action for Revitalized Teaching) was initiated in partnership with administrators and teachers of the two participating Tennessee school systems--Roane County and Chattanooga along with the State of Tennessee and private industry. The goal is to strengthen science and math teaching capabilities in these two selected systems that serve primarily economically disadvantaged and minority student populations, respectively. This will be done through joint planning by teacher teams at all levels within each system, by special opportunities for summer teacher research participation, and by providing access to Oak Ridge resources--both technical staff members and equipment--to assist in curriculum development and educational enrichment activities.

ORNL is serving as the lead Laboratory in a partnership with five other national laboratories, Los Alamos, Lawrence Livermore, Pacific Northwest, Argonne and Fermi National Accelerator Laboratory, and Oak Ridge Associated Universities in a multidisciplinary training program for teachers in grades K-8. Education and networking are key components of this initiative. The program is expected to serve over 400 teachers in a 3-year period involving "hands-on" activities that will impact conventional science curricula.

ORNL's base program in the precollege area, the Ecological and Physical Sciences Study Center, during the past fall semester passed the 20,000 mark in the number of students and adults served during its first five years of operation. Twenty-two (22) field and laboratory study units now are offered on a year-round basis.

ORNL is also participating with the local school system in an effort to help it recruit and retain quality minority teachers by providing the opportunity for summer employment. This relatively new program, Summer Teachers As Resources (STAR), differs from other teacher programs in that participants are drawn from all academic levels and disciplines.

ORNL during the 1989-90 academic year supported establishment and initial operation of the 130-acre environmental study center and wildlife sanctuary being developed by three area school systems--Oak Ridge, Clinton, and Anderson County--through the Clinch River Environmental Studies Organization (CRESO). Among the accomplishments have been: arrangements for (and installation of) an on-line NOAA Atmospheric Turbulence and Diffusion Laboratory meteorological reporting station at the site; assignment of a DOE Teacher Research Associate (DOE-TRAC) to work full-time during the Summer of 1990 on site survey activities and development of curriculum packages and resource kits for class use; and assistance in the organization and conduct of two teacher orientation workshops.

Special educational outreach activities centered on the new "Science-by-Mail" tutorial assistance program, the PALS (Partners at the Laboratory in Science) "adopt-a-school" network, and ORNL's Ecological and Physical Sciences Study Center were carried out as part of local efforts in support of National Engineers Week and this spring's planned National Science and Technology Week observance.

These activities linked the Laboratory's precollege program, local professional societies, and the East Tennessee Discovery Center. They involve both elementary and secondary students in area schools as well as adults. A special conference was held for undergraduate women on graduate study and career opportunities in science and engineering The keynote speaker for this conference was NASA Astronaut, Dr. Shannon Lucid, a biochemist. Dr. Lucid served as a mission specialist on the crew of the space shuttle Discovery in June 1985, and the Atlantis in October 1989.

Under the partnership agreement with the Oak Ridge Schools, the first three after-school "Science Seminars for Students" led by ORNL research staff members were offered.for junior high and high school students.

The Council on Research and Technology presented its ideas in its 1989 report Meeting the needs of a growing economy: the CORETECH agenda for the scientific and technical workforce. They recommend increasing federal financial support for both graduate and undergraduate education. In part, this involves grants to graduate students at a monetary level that can serve as a counter-incentive to substantial industry salaries. CORETECH also recommends that academic research facilities and instrumentation be modernized. I concur with both of these recommendations. From my experience at Oak Ridge National Laboratory, I am aware of the need to constantly upgrade the infrastructure of a facility. The phrase "penny wise and pound foolish" is certainly appropriate when you don't have the funds to perform periodic maintenance and repair. Delays in updating facilities and equipment, in the long run, can only result in loss of competitiveness.

On an individual basis, each of our organizations must take the initiative in solving the shortfall in the kinds of skilled people we will need. Particular attention must be given to women and minorities. We must enhance our interactions with high schools, colleges and universities. In February 1990, President Bush, Secretary Watkins, and Secretary Cavazos visited The University of Tennessee at Knoxville. While he was there, it was announced that contributions of $1 million each will come from the state of Tennessee, Martin Marietta Corporation (the operating contractor of Oak Ridge National Laboratory for the Department of Energy), and the Department of Energy to establish a Summer School of the South for Science and Mathematics for precollege students. An Academy for Teachers of Science and Mathematics will also be established as part of this program. It will be an advanced training ground for 200 of the region's most outstanding teachers. This overall UT/ORNL initiative will also explore and implement alternate paths for certification of science and engineering professionals who wish to enter teaching as well as provide summer laboratory research experience for science education majors as part of their undergraduate and/or graduate-level academic preparation for teaching careers.

At last week's first meeting of the Secretary's Advisory Board, Secretary Watkins reiterated his commitment to education. The recently issued Interim Report - National Energy Strategy (report DOE/S-0006P) states that implementation of a National Energy Strategy requires two types of educated people. Professionals and technicians with excellent mathematical and scientific skills are needed to carry out energy-related research and technology development. Similarly, it is vital that a general public be scientifically and technically literate to make well-reasoned decisions about national energy options. The report identified obstacles and options in precollege education, teacher training, underrepresented groups, university research and instruction, and the scientific and technical literacy of the public.

Direct interactions with colleges and universities are only part of the answer. Apprenticeship programs and technical training programs for skilled workers should be strengthened. Internal training and education can be enhanced and opportunities for advanced degrees might be increased through liberalization of educational allowances.

For many years, educators have decried the lack of parental involvement in education. Our schools are working diligently to eliminate the "hands-off" attitude held by too many parents by seeking input and attempting to involve parents in more decision-making. In the same way, our organizations must create the proper environment in research and development and other technical activities that will be "appropriate" for the changing work force. An analysis of management styles and organizational values must be included in any strategy for recruiting and retaining women and minorities. Cafeteria-style benefit plans may be appropriate to deliver the benefits to a socially and culturally diverse work force. Perhaps ORNL needs a day-care center, like Brookhaven National Laboratory and the Forrestal Building of the Department of Energy.

Science and technology are playing an increasing role in economic development, both in the United States and elsewhere in the world. Robert Solow of MIT, the 1987 Nobel Prize winner in economics, has studied the economic impact of science. In an interview, he has stated, "What I got interested in was the question of what makes a modern industrial economy grow...we owe it all to the growth of science and technology." This comment reflects the important role science and technology has in our economic well-being. Solow demonstrated that only a small portion of annual growth could be explained by increases in labor and capital. The key factor was always technology. If technology is the engine for increased economic growth, then education is certainly the fuel for the engine.

Senator **Gore**. Well, very good. Thank you. You were talking about the media there. Do you think we will see the day when in addition to "L.A. Law" we will have "Los Alamos Physics"?

Dr. **Trivelpiece**. I have often thought that what would be the right way to do this—the science programs that are done by "Nova", and so on, are first-class. They have about 11 million watchers. If it is a lousy program they have 10.5. If it is a great program they have 11.1. But by and large, that audience is stable. They will watch it come whatever.

What is needed, I think somebody like Bill Cosby needs to have a cousin of his show up periodically, be in the show, be attending a local institution and bring science in in a natural way. In other words, instead of trying to create programs that are science-intensive programs, get one of the popular programs to incorporate some element of science into it in a natural and human way, not in the way that it is the mad scientist, the Saturday-morning-cartoon scientist. Incidentally, pictures like that drawn by children in the Soviet Union show people being picked up at dachas or being picked up in limousines.

Senator **Gore**. Is that right? I remember Mr. Wizard. What is he doing these days?

Dr. **Trivelpiece**. Somebody else will have to answer that one.

Senator **Gore**. All right.

I asked Eric Bloch about the projections, and you said, Dr. Atkinson, you would say it is 100-1 that the projected problem is right on the money, or is going to be a real problem. Do the other two witnesses on this panel agree that it is a pretty certain thing?

Dr. **Atkinson**. I did not say that these projections will be realized, but I think there are a lot of forces at work—market forces, perestroika, the whole range—but there is going to be a major shortfall.

Senator **Gore**. If current policies are not changed, the odds in your view are 100-1 that we will experience a major shortfall in the number of science, scientists and engineers that we need beginning half-way through this decade and becoming even more serious by the turn of the century.

Dr. **Atkinson**. Even if we are very active in intervening, we are going to experience a major shortfall.

Senator **Gore**. Dr. Shalala.

Dr. **Shalala**. We also know a lot about the behavior of our own scientists and when they are going to retire. For example, Wisconsin uncapped the retirement age on faculty in 1984, so we are the only State that actually has gone through the experience. The retirement age has not changed in that period.

Senator **Gore**. Oh, is that right? So a lot of universities around the country are wondering what this change in the national law will mean, but your experience has been that the retirement age does not change that much?

Dr. **Shalala**. It stayed at about 65. There has been no significant change in the retirement age. We are going to lose—we are going to have to replace half our faculty over the next ten years. About 60 percent of those will actually retire and 40 percent will go some place else, so we have some feel for who is going to retire, who we are going to have to replace, and how many Ph.Ds we are producing ourselves.

We have produced the second highest number of Ph.Ds last year. Berkeley was first, and the number of Ph.Ds that are being produced is not increasing significantly in this country, so we have some sense, at least in terms of the teaching ranks, what is happening out there and a pretty good sense of the behavior of the faculty in terms of retirement now.

Senator GORE. All right. Did you want to add something, doctor?

Dr. TRIVELPIECE. Well, at 100-1 odds, I will bet on Ben Hur to lose. But I think it is clear the direction is exactly right. It is a problem. Making such forecasts, however, are based on the assumption that there are no changes in the current circumstances in which the assumption is made, and those things change very, very rapidly.

I remember that there was a shortfall of funding for scientists and engineers at the tail-end of the Nixon Administration, and I know that many fellowships were cut off during that period. That was an incredible sense of poor timing, in that they were shut off just at exactly the time such that if you had continued them they would have been meeting a future demand.

The roller coaster effect is very serious, so what I would put into this is the need for continuity, stability and predictability on the basis of academic institutions and laboratories for funding. The roller coaster effect is a very serious negative issue, and it does occur all the time.

Senator GORE. Now, on another subject, I asked Mr. Bloch about how he might spend extra money as between different levels of the educational pipeline, and he emphasized pre-college and graduate education. Am I correct in assuming that at least two members of this panel would apportion the funding differently?

Dr. ATKINSON. Mr. Chairman, I would not even answer a question like that. I mean, this is a Government-wide issue. We have tremendous shortfalls in our support for science. You heard some remarks about the individual investigator. We have tremendous problems at the K through 12. The graduate education issue I think is a disaster.

I think one needs, which you suggested the President's people should be putting together, a plan, and how you would spend $100 million, I would not—I mean, I hate to tell you this, but that would buy on my campus about two engineering buildings and it is hardly worth discussing at the national level.

Senator GORE. You do not want it either, Dr. Shalala?

Dr. SHALALA. No, I will take it. I think that if I was going to target it I certainly would focus on women and minorities, but again the pipeline problem. If you throw it into pre-college and you do not have all the other pieces in place, it will not have the kind of impact that you want to have, and while it is true we could create some demand just by putting in graduate fellowships, I think all of us are wary about misleading any of you that if you we it in one place it is going to straighten out the problem along the pipeline, and that is our real concern.

Senator GORE. Dr. Trivelpiece.

Dr. TRIVELPIECE. I would like to comment. There is a distinction between technology push and technology pull. Quite frequently, technology push misses the point in that it tends to try to push on something that is not necessarily wanted. Technology pull quite frequently works more effectively.

I would ask you to keep in mind that particular kind of an idea in this circumstance in that funding of activities that create pull towards scientific activities may be more effective in the long run than simply trying to get at the bottom end and push.

Dr. Shalala mentioned the issue of the Hubble telescope and their involvement in it. I have seen many projects of that sort cause graduates and undergraduates to become instantly interested in them and want to become involved. Many of my own students over the years said that I visited such and such a facility and I knew right then what I wanted to do for the rest of my life. They do have a very interesting effect on inspiring people. So if that element of funding of pull, rather than push could be taken into account, I think some benefit would be gained.

Senator GORE. I really agree with that, and I have made that argument in support of the National Research and Education Network, the information superhighway network which will link advanced computing facilities around the country, and I know, Dr. Atkinson, you have some concerns which we are not going to really have time to get into today, about ways in which universities can wire with fiberoptic cables to take full advantage of the network that we are going to build, but I do believe very strongly that this network, once in place, will pull students towards science and engineering in a very powerful way.

Let me just ask a couple more questions briefly before recognizing Senator Kasten. First of all, do you all agree with what I just said about the ability of this network to pull students toward science and engineering?

Dr. TRIVELPIECE. I certainly do, and it sends a message. There are two kinds of messages. One is that we believe that students ought to pursue careers in mathematics and computers, and by the way here is an abacus, or, we believe they should pursue it, and by the way, here is a world-class means by which they can do so. The difference between those two messages is something that the very bright students capture very easily and accurately.

Dr. ATKINSON. I agree totally. I think it is a very important initiative, and from another perspective I think it is going to have a tremendous impact on our competitiveness in terms of developing new technologies. This is one place where, if we wanted to talk about a technology policy, putting money into a network like this would have tremendous spin-off effects in terms of our ability to create new companies, new activities in the nonacademic sector.

Dr. SHALALA. I agree with that, too, and it is a perfect role for the National Government.

Senator GORE. Well, great. I certainly, of course, agree with that, and this Committee on a bipartisan basis reported the bill out—indeed, unanimously.

What kind of library resources and databases would you recommend making available to students over such a network, and how could we accelerate the development of new learning technologies to take advantage of this network?

Dr. TRIVELPIECE. It is a one-word answer: everything.

Senator GORE. Everything. All right.

Senator Kasten.

Senator KASTEN. Mr. Chairman, thank you.

Let me ask Dr. Shalala, but I would be interested in the others comments as well, we are seeing the number of Ph.D.s declining. A recent NSF study noted that a possible reason is the time that doctorate candidates seem to take to obtain a degree.

In the last 25 years graduate students have been taking roughly three years longer than in the period before 1967 to get certain scientific Ph.D.s. I do not know if this has anything to do with your risk/reward, but it is going to take them three years longer to get to where they are going.

What is going on? Is the reason for the increased time the increased body of knowledge, or are we seeing people going to school part-time? Or are we seeing people deciding to spend part of their time in something other than directly working toward their Ph.D.? Why is it taking three years longer? And should this be of interest to this committee and to our society as we are dealing with some of the questions that you are wrestling with this morning?

And let me start with Donna Shalala, but I would be interested in all of your comments.

Dr. SHALALA. I think, Senator, it is all of the above. If we switched basically from fellowships and traineeships directly to research projects the chances are the students are working a certain number of hours and that probably is stretching out some of their scientific training.

We also do have an expanded body of knowledge. And that has somewhat slowed down in certain fields the timing, in terms of how people are finishing their degrees. So that it is a combination of factors on how long it is taking students to finish their degrees. I should point out, for undergraduates, too, it is taking them longer to finish their degrees. Some of that is related to working, and some of that is related to students coming back a little older.

But my sense of what is happening here is really the pipeline does not have the level of financial support which is as focused, and that students are working longer on research projects, and therefore it is taking them some time to get their degrees.

But Dick also has a group of scientists at his place.

Dr. ATKINSON. Well, I think it is all of those factors and the uncertainty of funding is part of it. But in my more extended remarks in discussing a fellowship/traineeship program, I would put requirements on the university that would ensure an increasing number of Ph.D.s are produced. And I believe in most fields of science—in all fields of science, one should complete the degree between four and five years. I think there have to be very peculiar reasons to justify going beyond five years. And universities, for lots of reasons, probably have been too lax.

Senator KASTEN. But why is this happening? I mean a law school degree still takes three years.

Dr. ATKINSON. A medical degree is four years.

Senator **Kasten**. An MBA is still two years. And it seems like the Ph.D.s., particularly in math and science, but also—what is going on here?

Dr. **Atkinson**. The funding is very uncertain for students. It is very hard for us to put packages of funds together to guarantee a student four years of support. After Sputnik, when a student entered graduate school there was a four-year program of support available.

Today, particularly with all the problems that we have, it is very hard to put together funding programs so students can start. They have to get involved in additional research projects. They have to do things to support themselves. Plus, the universities have been under strain in terms of maintaining their research programs, and it is very convenient to hold a student on, to have him there to participate in the research programs.

And frankly put, the job market has been a little soft through the 1980s and will continue to be a little soft for a couple of more years. And all of these factors have made us a little lax.

I think the universities are somewhat at fault here.

Senator **Kasten**. Dr. Trivelpiece.

Dr. **Trivelpiece**. My graduate adviser at one stage told me that, look, you are big boy, you have got to find your own problem to work on. That is a—the hard sciences in particular, it is a degree in being able to do intercollegiate competitive research. There is not this prescribed set of things that you can do.

You can check off two languages, then two orals, or an oral and an examine. Ultimately you have to do a thesis and that has an indeterminate time factor built into it in order to do a piece of credible research, report it, and get it, out.

There are some institutions, and my own, Caltech, was one in which it still is true, in which there is a finite limit on the amount of time you can spend working toward a Ph.D., and it is 18 quarters of registration after your B.S. degree. If you have not done it by then, it takes some fairly fancy pleading in order to be able to continue.

The object is to get people in and to get them out. I think that other academic institutions could profit by that type of a more rigid format of getting people through the system on a mechanical limit basis.

Dr. **Shalala**. Senator, one of the reasons that we say all of the above is that many of us have not focused as much on the science Ph.D.s, because they seem to get through fairly quickly. When you look in the humanities and in some of the other disciplines, you are talking about really long spans, because there is no funding there.

I think the science one, we are going to do something about, particularly as the market opens up, because the pressure will be on us to push them out, and also to get larger number [illegible] people to fill that market. And as the funding gets more secure, wherever we are able to put together those four-year packages, we get our students through and out. It is where it is uncertain funding that the students have to spread out their time a little bit.

But when we are dealing with a couple of years, we are really able to deal with that.

Senator KASTEN. It would seem to me that someone starting a program wants to have a beginning, a middle and an end. And whoever is administering the program ought to be able to have a beginning, a middle and an end also. And whether it is 18 quarters, that sounds like a long time to me, but maybe that is not a long time in the business that you are all in.

Dr. TRIVELPIECE. It goes by with the speed of light.

Dr. SHALALA. Yes.

Senator KASTEN. But we have not had this kind of expansion, if you will, in other graduate degrees, at least that I am aware of, particularly business school and law school. People are trying to get through and get to work. Now, maybe the Ph.D. students are not trying to get to work because they are going to end up——

Dr. TRIVELPIECE. They are in a prescribed program.

Dr. SHALALA. They are basically doing course work in those programs, not producing a major piece of research for a dissertation. And often our students, as part of a team, are producing that piece of research.

Dr. ATKINSON. Well, I agree with both of the remarks on the problems of doing research and completing it in a timely way. But I will assure you that if you mounted a fellowship program where you said the money was contingent on a five-year Ph.D., we would be producing people in five years of great quality.

Dr. TRIVELPIECE. Guaranteed.

Senator KASTEN. Yes. I would guess you are right.

Dr. Atkinson, I am trying to figure out, how your page 21a chart compares with the charts that we have got from the National Science Foundation.

Dr. ATKINSON. Yes. Which one is that?

Senator KASTEN. Your 21a chart showing research fellowships and assistantships, talking about federally supported student stipends at the doctoral level, and showing how that is going down. And then you take the National Science Foundation chart, which is on the second page of the National Science Foundation handout on education and human resources.

And if you take our blue category, which is funding for "graduate and others," you see that amount increasing dramatically, not only the overall amount—in 1985 it was $137 million, and we are now at $463 million. I cannot read exactly how much the blue has increased, but I can see that it is about four times what it was in 1985. How does that match up with your chart on 21a? All I can see is that we have increased spending on graduate and other programs but what we have not done is increased spending on federally supported student stipends at the doctoral level, which is your chart 21a.

What are we spending these increased federal graduate funds on? And why do not the charts match?

Dr. ATKINSON. Senator, let me just comment a little on the 21a chart. You will note that the black area is research assistantships, and NSF might be—I mean I do not know the breakdown of the figures, but you can see that has gone from about 20,000 way up to about almost close to 40,000 fellowships. Those are numbers.

So as we have cut back dramatically in fellowships and traineeships across the government, there has been a corresponding increase in research assistantships but not nearly enough to make up for the changeover. So we have gone from a total of supporting about 80,000 graduate students a year on fellowships, traineeships and assistantships, down to about 45,000 or 46,000.

Senator KASTEN. I am trying to figure out where is this money going?

Senator GORE. Would my colleague yield for a moment?

Senator KASTEN. Yes.

Senator GORE. I think that one reason the charts do not match up is they start at a very different point in history. The colored graph provided by Mr. Bloch begins in fiscal year 1982, if I am looking at the same one.

Senator KASTEN. This is 1982 and this is 1969.

Senator GORE. Yes. And this starts in 1969. There was, if I am not mistaken, a fairly dramatic falloff from the late 1960s to the 1980s, so that it is possible that this graph, if it had the 1960s and 1970s in there, would have had a down slope before it comes back up.

I know that after Sputnik and then at the beginning of the moon program there was a significant increase in the amount of funding. So that may be the explanation for a lot of the discrepancy there.

Dr. TRIVELPIECE. I cannot comment specifically on the numbers, but I would like to comment on the issue, which was that I was doing research in a university during this period and had graduate students working for me, and there were those that you tried to get who had a fellowship attached to them—they had won a competitive fellowship. If you could get them to join your program they essentially came into your activity as a freebie.

On the other hand, you had a certain amount of assistantship money of your own and you would go out and try to recruit good students from within your own academic institution to join your particular research activities.

What I have watched happen and what I think that Dick is trying to get at is that there was a reduction in the number of the freestanding fellowships during that period. And I think that that is unhealthy. There really should be leading students who have in their hand a fellowship that permits them to go with any faculty member at any academic institution. That benefits the system greatly. They should not be 100 percent that way, but the percentage that have that capability now is far too low.

Dr. SHALALA. Senator, let me give you the numbers for Wisconsin. In 1980 we had 981 fellowships and NIH traineeships. In 1989 we had 878. That is a decline of 10 percent. In terms of the number of graduate students on research projects, in 1980 we had 2,227, and in 1989 we had 2,645, and that is an increase of almost 20 percent.

So that what has happened is that we have increased the number of students that are working on research projects, and decreased the number that are on traineeships and fellowships.

Now that, in part, has played a role in lengthening the time.

Senator KASTEN. And that is consistent with this chart?

Dr. SHALALA. Yes, that is right.

Senator KASTEN. Well, what I would like to suggest, Mr. Chairman, is maybe we ought to fill in these years between 1989 and

1969, and if it is in fact a dip, maybe the last three or four years we have been working our way back up. I am not sure.

Dr. **Atkinson**. Not in terms of the fellowships and traineeships, but possibly in terms of research assistantships.

Senator **Kasten**. In terms of research assistantships it has been going up. But we ought to look at the whole and see if there is in fact a kind of a U-shape here in which we are on our way back up, and that would be helpful.

Dr. **Shalala**. You see, it is hard to read, Senator, whether that is having an impact on the number of years or on the funding. Those research assistantships could be only two-year commitments or three-year commitments, as opposed to the fellowships and the traineeships that might buy the whole period of time of someone's training. So it is a mixed bag here in terms of whether we have actually gotten more secure as a result of the decline in fellowships and assistantships.

Senator **Kasten**. Well, I guess what I am suggesting is that we ought to look at the priorities. And I agree with everything that you all have said and the witness before, but at the same time I look at a chart going from $137 million in 1985 to $463 million in 1991. Maybe somehow with these dramatic increases we are not putting the money in the places that you are saying it needs to go.

And that is what I am trying to reconcile.

I thank you, Mr. Chairman.

Senator **Gore**. Without objection, we will adopt your recommendation, Senator Kasten, and ask the National Science Foundation to fill in these numbers going all the way back to 1969. I believe it will show that there was a tremendous dip and that we are now recovering. And in fact, I think with some certainty that in 1981 there was a cliff, the edge of which funding fell off, and that we are steadily recovering from that.

I have just been informed that we have a series of votes that will begin any moment now.

Your statements have been excellent here today and have helped us tremendously in our efforts to understand this problem. I want to say at the conclusion of this hearing that we intend to continue a major focus on this particular subject. The other committees are interested in solving this problem as well. We intend to complement and assist their efforts. But from our standpoint here, we are going to continue a major focus on this.

And thank you very much for your help, all three of you.

[Whereupon, at 12:03 p.m., the hearing was adjourned.]

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